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A MANUAL
OF
DRAINAGE
FOR
FARMERS AND LAND-OWNERS,

By EDWARD WASELL, Civil Engineer,
M. INST., C.E.,
INGERSOLL, ONTARIO, CANADA.

CONDENSED INTO THREE CHAPTERS:

CHAPTER I.
CONTAINS
Tables of Average Temperature; Rainfall; Value of Farms in every State and Pyovince of North America; with a Series of Tables for ascertaining the number of Acres Drained by Tiles of different sizes;

CHAPTER II.
Remarks upon Transportation by Rail, and General Remarks upon Railroads.

CHAPTER III.
House, Village, Town, and City Drainage in general.

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TORONTO.

PREFACE.

" A bold peasantry, their country's pride,
When once destroyed can never be supplied.

SOMEBODY has said "that he who is the means of making two blades of grass grow where only one grew before is a benefactor of his kind." With this end in view, this little book now sees the light.

This Manual of Drainage is now submitted to the farmers and land-owners with a sincere wish that they may receive as much benefit from its perusal as the author has received from the study of so interesting a subject.

The Tables are original, and they will enable anyone to answer the question, " What size of pipe do I require to drain my land ? " They are the result of extensive reading scattered among numerous papers, pamphlets and books, while actively engaged upon drainage works.

The chapter on Drainage of villages, towns and cities comprises the essential knowledge most wanting, in our opinion, and without which no sewerage works can be satisfactory.

In preparing this chapter, recourse has been had to the printed reports and papers read before the several learned societies, among them, the Minutes of Proceedings of the Inst. C.E., and many printed reports on sewerage by different authors both in England and America, in order that, though brief, it may be reliable.

While believing that agriculture is the foundation of all permanent prosperity, and that without prosperous farmers all other industries must eventually languish, this little book is respectfully inscribed to the farmers of North America.

THE AUTHOR.

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A MANUAL OF DRAINAGE.

CHAPTER I.

THOSE who may search herein for something of literary interest will be disappointed. This has been written for common men of common sense who have not time to study excellencies of style or diction. What a misnomer to say common sense, when it is the most uncommon sense. Though agriculture is of a common nature, it is not so unimportant an industry as certain people think, or appear to think, it is.

A moment's reflection will convince the most of us that all the people upon this earth must live of the productions of the soil. The earth is the great mother—the foundation and fountain of sustenance to every one who lives upon it.

While the factories may flourish, wealth abound, and the protected professions and business-men flourish, the farmer, though he had the start of them all, languishes in the race; and it is no uncommon thing to hear said, "farming does not pay," while the active brains of the coming generation of farmers are thinking of entering the "hives of industry" in order to study law, medicine, and other protected professions, trades and businesses.

Why farmers should be interested in the legislation of the country, will appear from the following statement of values: The value of each state has been arrived at by capitalizing the average annual value of farm products for the last three years, less operating expenses, at current rates of interest. This is the true way of estimating the value of a farm or a state, because property is worth what it will fetch in open market. The amount capitalized for which a farmer sells his produce, after deducting working expenses, is the value of his farm. Suppose a farmer realizes $1,000 per year from his farm, then, having regard for the value of money, his farm is worth about $20,000, for money is worth about 5%.

TABLE SHOWING AVERAGE TEMPERATURE, RAINFALL AND ESTIMATED NET AVERAGE VALUE OF FARMS IN NORTH AMERICA.

Name of State or Territory.	Area in Square Miles.	Estimated total value of Farms.	Nunber of Farms.	Estimated value per acre.		Average Temperature Fah.		Average Rainfall.
				Cleared.	Woodlnd	Summer.	Winter.	
United States.		$		$ c.	$ c.			
Alabama	52,250	120,000,000	135,865	6.50	4.10	79° to 83°	46° to 52°	55 inches.
Arizona	113,020	9,000,000	....	....	....	71 — 73	34 — 42	14 "
Arkansas	53,850	117,500,000	94,450	11.80	3.50	79 — 82	42 — 51	40 to 55 "
California	158,360	395,000,000	35,940	27.20	8.60	58 — 69	50 — 55	20 "
Colorado	103,925	55,100,000	....	....	....	72 — 74	25 — 37	15 to 20 "
Connecticut	4,990	180,200,000	30,600	29.00	24.50	68 — 74	27 — 40	44 "
Dakota	149,100	62,200,000	....	....	....	63 — 71	0 — 27	17 "
Delaware	2,050	55,000,000	6,660	19.00	15.00	69 — 74	30 — 38	50 "
District of Columbia	170	5,500,000	....	....	....	....	....	....
Florida	58,680	30,200,000	23,440	9.50	3.10	80 — 83	55 — 61	57 "
Georgia	59,475	168,000,000	62,105	6.95	5.45	79 — 83	46 — 52	48 "
Idaho	84,800	9,100 000	....	....	....	68 — 75	30 — 40	18 "
Illinois	56,650	1,500,000,000	255,745	33.00	23.00	76 — 80	25 — 37	35 "
Indiana	36,350	960,000,000	194,015	30.50	27.00	73 — 78	29 — 41	43 "
Indian Territory	6,496	31,500,000	....	....	....	77 — 82	35 — 48	20 to 36 "
Iowa	56,025	890,000,000	185,355	27.40	39.40	70 — 76	21 — 37	43 "
Kansas	82,080	450,000,000	10,500	12.00	19.00	74 — 79	25 — 35	31 "
Kentucky	40,400	455,000,000	166,460	18 90	12.90	75 — 80	34 — 44	49 "
Louisiana	48,720	177,800,000	48,300	14.40	3.60	81 — 83	53 — 61	51 "
Maine	33,040	152,000,000	64,310	12.90	12.70	60 — 69	23 — 38	45 "
Maryland	12,210	245,000,000	40,600	24.70	35.50	73 — 79	33 — 41	41 "
Massachusetts	8,315	220,000,000	38,410	85.00	43.30	66 — 71	27 — 38	45 "
Michigan	58,915	740,000,000	154,010	34.40	20.30	67 — 82	20 — 36	30 "
Minnesota	83,365	300,000,000	140,000	20.00	15.00	67 — 74	5 — 30	25 "
Mississippi	46,810	174,600,000	111,880	7.90	3 80	70 — 83	47 — 56	54 "
Missouri	69,415	600,000,000	215,580	14.55	8.30	75 — 80	30 — 43	42 "
Montana	146,080	44,500.000	....	....	....	55 — 65	17 — 30	12 "
Nebraska	76,885	213,000,000	63,390	8.95	25.90	72 — 78	20 — 24	25

Nebraska	76,885	213,000,000	63,390	8.95	25.90	72 — 78	20 — 24	25 "
Nevada	110,700	22,000,000	1,410	....	....	66 — 73	30 — 38	20 "
New Hampshire	9,305	115,000,000	32,190	15.00	32.00	63 — 69	23 — 38	40 "
New Jersey	7,815	285,000,000	34,310	82.60	56.90	66 — 73	32 — 42	45 "
New Mexico	122,580	37,500,000	....	....	....	66 — 70	27 — 37	17 "
New York	49,170	1,522,000,000	241,000	58.50	40.90	67 — 73	22 — 36	32 "
North Carolina	52,250	204,000,000	157,610	9.80	5.55	76 — 80	46 — 51	43 "
Ohio	41,060	1,687,000,000	247,200	47.60	41.40	68 — 73	27 — 38	38 "
Oregon	96,030	61,700,000	16,220	21.80	4.50	62 — 68	38 — 46	22 to 64 "
Pennsylvania	45,215	1,464,000,000	156,360	45.80	29.80	70 — 75	31 — 42	44 "
Rhode Island	1,250	39,000,000	6,220	....	....	64 — 71	29 — 43	42 "
South Carolina	30,170	103,000,000	93,870	6.25	8.65	79 — 83	50 — 54	43 "
Tennessee	42,050	310,000,000	165,650	13.00	7.30	75 — 81	37 — 48	45 "
Texas	265,780	260,000,000	174,200	9.00	4.00	82 — 84	53 — 63	33 "
Utah	84,900	21,500,000	9,455	....	....	69 — 77	29 — 40	24 "
Vermont	9,565	163,000,000	35,530	15.30	17.80	66 — 71	18 — 33	34 "
Virginia	42,450	324,000,000	118,520	9.45	7.50	75 — 80	40 — 48	38 "
Washington	60,180	52,260,000	....	....	....	59 — 62	37 — 44	24 to 143
West Virginia	24,780	200,000,000	62,700	21.10	9.40	70 — 75	34 — 42	45 "
Wisconsin	56,040	537,000,000	102,950	26.30	19.60	63 — 70	19 — 31	30 "
Wyoming	97,890	61,364,000	....	....	....	63 — 69	23 — 33	15 "
Total	2,951,379	15,829,524,000						
British Possessions.								
British Columbia	361,346	6,000,000	....	....	....	58° to 62°	36° to 43°	50 inches.
Manitoba	123,200	52,100,000	....	....	....	85 — 55	0 — 10	17 "
New Brunswick	27,174	52,050,000	....	....	....	60 — 66	10 — 35	50 "
North-West Territories	2,665,177	8,600,000	....	....	....	85 — 55	0 — 10	17 "
Nova Scotia	20,907	54,400,000	....	....	....	60 — 70	10 — 40	50 "
Ontario	221,733	540,000,000	....	....	....	85 — 60	10 — 40	30 "
Prince Edward Island	2,133	26,880,000	....	....	....	64 — 70	20 — 30	50 "
Quebec	188,688	250,980,000	....	....	....	85 — 60	0 — 30	40 "
Total	3,610,257	991,010,000						

These estimates include all farm property and products —such as buildings, farm implements, live-stock, orchard produce, rice, peas, beans, potatoes, turnips, cotton, sugar, molasses, tobacco, hay, oats, barley, wheat, corn, wool, flax, hemp, rye, maple sugar, etc.

Thus it is shown that the yearly value of farm productions, etc., of the United States and Canada, after deducting reasonable working expenses, interest on the investments, etc.—for whether the farmer owns the farm or rents it makes no difference in this case—when capitalized at about 5%, sums up to the enormous amount of $16,820,-534,000. What becomes of the absurd contention of certain "politicians" who say that the farmers' occupation is small and inconsiderable when compared with that of the manufacturers? For the year A.D. 1888, the total earnings of farmers in North America may be estimated, for the United States, $3,388,150,000; and for Canada, $251,890,000.

DRAINAGE.

Without further preliminaries, we now proceed to discuss drainage. The following tables, Nos. 1, 2, 3, 4, 5 and 6, were prepared originally for a friend, but having used them in our own practice, and found them of value, we determined to publish them along with some other memoranda gathered from time to time, the result of which is this hand-book of drainage.

The first thing to be done in undertaking drainage works, is to select a suitable outlet. This point will usually be at the lowest part of the farm or into a running stream. The common law, which is common sense, gives a farmer a right to drain into a stream, even if on his neighbor's farm, and to drain his natural water—that is the rain which falls from the clouds—wherever it runs naturally. The neighbor but receives what nature intended he should receive, but artificial drainage accelerates nature in her operation of carrying the water to its natural outlet.

Each drain may have an independent outlet, or all the drains may run into one main drain with one proper outlet. Each drain, where practicable, should be cut at right

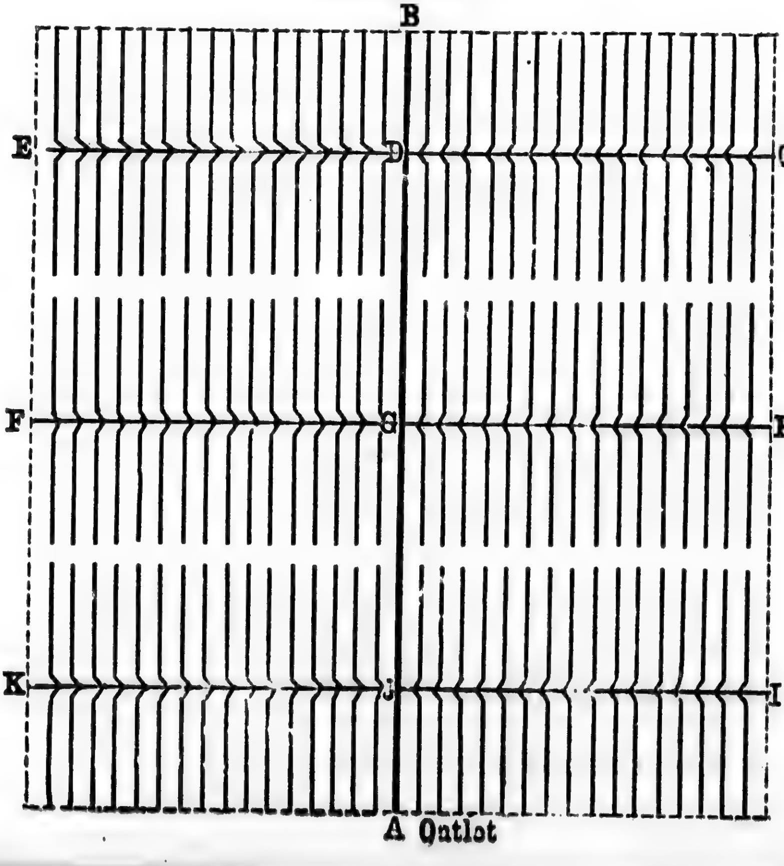
angles to the slope of the ground, and at its outlet be protected by a wooden box with an iron grating, or some other device or contrivance for effectively preventing vermin from getting into it and building nests or creating any obstructions to the free flow of the water through the drains. As much fall as practicable should be given to all drains—unless the farm is situated on hilly ground where the fall for drains will always be ample—but much more skill and exactness are required in laying out drains of small fall, and such drains will cost the farmer more for skilled labor, if he intends that they shall be effective.

The next thing to decide is the depth and distance apart to put the drains. One is dependent on the other. A moment's reflection will show us that all water, whether poured on the land from the clouds or put on in some other way, will sink, by the law of gravity to the lowest level. Our drain should intercept it on its way to the lower level. There is the friction, dependent on the porosity of the soil, to retard its flow on its passage down to the drain. In a great portion of North America the frost penetration is considerable. In all circumstances the drain should be down below the frost line. However deep it may be to the frost line, unless in the polar regions, so far will the earth be disintegrated and pulverized by the action of frost, and so readily receive the rainfall. Now, the rain penetrating the soil, falls at a certain angle or inclination until it reaches the drain built to receive it. This angle or rate of inclination will depend upon the rapidity and compactness of the rainfall, the nature and porosity of the soil, the steepness or flatness of the ground, the temperature and moisture of the atmosphere, and other things affecting it less or more. We will first deal with a free soil, tolerably level, which includes gravels, sands, peats, loams, and every kind of mixed earth, which compose, probably, the greater bulk of soils in North America. Of these soils Liebeg says, "Lands of the greatest fertility, contain argillaceous earth and other disintegrating minerals, with chalk and sand in such proportion as to give free access to air and moisture." In order to drain this sort of land we may place the drains, generally, eighty feet

apart and five feet deep, as is shown in diagram on next page. The water, it is estimated, will percolate through this kind of soil at an inclination of one in ten, thus leaving over a foot deep of drained land in the middle of each space of eighty feet between drains. Let the following Diagram represent a quarter-section, or one hundred and sixty acres. Then the dotted line will represent the limits of the quarter-section. Let the solid black lines represent drains.

Then the quarter-section is divided by a main-drain—A J G D B, emptying into the river, stream, or other outlet at A; and the sub-mains I J K, F G H, and C D E, empty into the main-drain at J, G, and D, respectively. From inspection we find that the quarter-section of 160 acres is divided for drainage purposes into six equal parts, and in these six equal parts of nearly 27 acres each, there are 16 minor-drains, all joining the sub-mains.

DIAGRAM No. 1.



I J K, F G H and C D E, at common junctions. Now, allowing the fall to be uniformly 1 in 400, and the rainfall 30 inches, we have to provide as follows: (See table No. 4.)

Portion A J	440	lineal feet of	9-inch	pipe @ $0.08	$35.20
" J G	880	" "	7 "	" 0.05½	48.40
" G D	880	" "	6 "	" 0.04	35.20
" D B	400	" "	2 "	" 0.01	4.00
½ Sub-mains	3840	" "	3 "	" 1.25	48.00
½ Sub-mains	3840	" "	2 "	" 0.01	38.40
Minors	76,800	" "	2 "	" 0.01	768.00
Estimated cost of pipes					977.20
87080 feet trenching and sundries					4,354.00
Total cost					$5,331.20

or total cost about $33.32 per acre. We could hardly get a case exactly like this, except on the prairies, but this example serves to illustrate the use of the tables. We take A J, a 9-inch pipe, because at a fall of 1 in 400 the table gives 200 acres; and the whole quarter-section must drain through the pipe here; and we take this, as it is always best for the pipes to be on the safe side, a little too large. The next portion, J G takes the water through it that comes into the main-pipe at the junction G, this is evidently, ⅔ of 160 acres, or nearly 107 acres rainfall. The table gives this nearly exactly. The next portion of the main-pipe is G D. This has to take the remaining third, or a little over 53 acres rainfall, which the table gives—taking the next higher figure—75 acres, which takes a 6-inch pipe. Now, the last portion of the main-pipe has but to carry off the rainfall of a few acres, so we make it two inches in diameter. The portions of the sub-mains, next the main-drain, have to carry more water that those portions next the limits, consequently we make them 3 inches in diameter, and the balance the same as the minor-drains, 2 inches in diameter. The prices of labor and material, of course, will vary.

Wetness of soil is often produced by water confined further down below the surface than the usual depth of drains. An impervious subsoil will often demand drains closer together than 80 feet, and, consequently, more of

them than where the soil is porous. The texture of the subsoils must be consulted, and the depths of the drains, if below the frost line, proportioned accordingly. To form an approximation of how deep to dig trenches for drains, begin by putting down one drain five feet deep, then dig a hole at a point 40 feet on one side, and if the water stands in it 12 hours after a rain-storm at less than one foot from the surface, then 80 feet will be too wide apart for the drains. Try again in another place by digging a hole 20 feet from one side, and if the water is there at 2 feet below the surface, its inclination on flowing into the drain, is about 1 in 7, and the drains must be about 50 feet apart to leave over a foot of dry land between drains. Stiff clay-soil may require to be drained, where the frost admits of it, at shorter distances between the drains—say at 40 feet apart and four feet deep; thus admitting the soil to become ærated and pulverized by the weather. The use of an auger, in some cases, will facilitate the operation of determining how deep it may be necessary to lay drains in order that they may do their work effectively. But there can be no doubt that deep under-draining promotes the æration and disintegration of the soil to a greater extent, generally, than shallower drains. Any depth less than three feet will generally prove unsatisfactory. It is to be expected that the general drainage of the land will lead to floods, as the water will be brought off the soil much more rapidly than before. The rivers and streams will be swollen proportionately, so that a good outlet is almost a *sine qua non* in every system of drainage.

EXPLANATION OF THE TABLES.

Table No. 1 shows the velocity per second of water flowing through ordinary underdrains open at each joint for the admission of water percolating through the soil, and is calculated from a formula $\sqrt{F \times D \times 2}$, where F is the fall per thousand, D is the diameter of the drain, and 2 is a constant, all in feet. Repeated experiments, conducted under different conditions, show that this formula is as nearly correct as it is possible to be for drains about

4000 diameters in length. There may be people who will tell you that more water will flow through a pipe than is given here by this formula, but, if there be such, it is questionable whether such persons know what they are talking about. A drain is not for the conveyance of water under a "head" such as water-pipes closed at the lower end and at each joint; but a drain is, necessarily, open at the outlet and at each joint—at about every foot in its length—to admit the rainfall which percolates through the soil. Hence, friction plays an important part in retarding the velocity of water flowing through farm-drains. This table will serve in nearly all circumstances, and where the exact fall is not given in the table it can be supplied by approximation by taking out the next higher and lower, and taking the mean of the result, and so on, until a satisfactory one is obtained.

Table No. 2 shows the number of cubic feet per second of water flowing through farm-drains at different inclinations or falls, and of different sizes when flowing full. From tables 1 and 2 the rest have been calculated.

Tables No. 3, 4, 5, and 6, show the number of acres which can be drained when the rainfall is 20, 30, 40 and 50 inches per annum respectivly, by circular drains of different sizes.

The rainfall does not get into the drain in the manner in which it does into a sewer, but gradually percolates through the soil until the amount of water not carried off by evaporation and absorption finds its way into the drain. In these tables the evaporation and absorption are estimated at $\frac{2}{3}$ of the whole rainfall, so that but $\frac{1}{3}$ finds its way into the drain, which is near the average in North America.

The total rainfall in 24 hours has been taken at $\frac{2}{10}$ of an inch for 20 inches rainfall per annum; $\frac{3}{10}$ of an inch for 30 inches rainfall per annum; $\frac{4}{10}$ of an inch for 40 inches rainfall per annum; $\frac{5}{10}$ of an inch for 50 inches rainfall per annum. Much greater falls of rain will occur at intervals, but these amounts when distributed over 24 hours, are, it is believed, within the mark.

20 inches rainfall is applicable to the following named states and territories:

Arizona, parts of California, Colorado, Dakota, Idaho, Montana, Nevada, New Mexico, Wyoming, Manitoba and the North-West Territories.

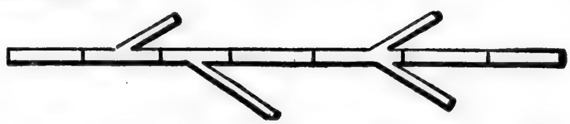
30 inches rainfall—Parts of California, Illinois, Indian Territory, Kansas, Michigan, Minnesota, Nebraska, New York, parts of Oregon, Texas, Vermont, part of Washington Territory, Utah, Wisconsin, Ontario, and part of Quebec.

40 inches rainfall—Connecticut, Indiana, Iowa, Maryland, Massachusetts, Missouri, New Hampshire, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennesee, Virginia, and West Virginia.

50 inches rainfall—Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maine, Mississippi, New Jersey, parts of Washington Territory, British Columbia, New Brunswick, Nova Scotia, Prince Edward Island and parts of Quebec.

In districts where the rainfall is confined to a portion of the year called the "Rainy Season," provision may be made to carry it off by larger drains. Say, in districts where most of the rain falls in three months, table No. 6 may be used. We consider provision for fifty inches of rainfall ample for any district; for if the drains did not carry it off in 24 hours, they would in 36 hours after the rain stopped.

Junctions of drains should always be made by junction-pipes, made thus:



which are easily obtainable from any drain-pipe factory—and joined by a curve in the direction of the current to facilitate the flow of water.

Pipes of less diameter than two inches are not recommended for under-drains. Such pipes may be of sufficient capacity, but the saving made by their adoption would not compensate the farmer for the risk of obstructions which sometimes occur in them.

A drain which has been well made will last 50 years, and will pay for itself in from 3 to 5 years. Be sure to use wooden outlet pieces protected by an iron grating; and lay the tiles from the lowest point, upwards.

In sandy, or other very porous soil, put straw in the bottom of the drain-trench. In quicksand, use rough hemlock or other boards, at the bottom of the drain-trench, in addition.

Pages 6 and 7 contain information referring to temperature, rainfall, etc., which is approximately correct. It must be borne in mind that in states and territories of such magnitude the average temperature and rainfall only are given in these estimates. The exact temperature and rainfall may be more nearly obtained by persons living in the particular district. Intending settlers in any of these states or territories are cautioned against the rose-colored representations of paid agents of land, state or territorial officials, because they will be but doing their duty to their superiors, their paymasters, by doing all they can to get settlers. A certain professor was recently very enthusiastic about obtaining settlers for a north-western district; but the enthusiasm was accounted for when the public accounts were published, and his name was mentioned as the recipient of large sums of money to induce farmers to settle there.

If you value your health, and are bound on changing your place of abode, select a section of country in which to settle that is not subject to sudden changes, and one that is free from malaria. Move with caution and with all the information obtainable from disinterested sources. If such information cannot be got, rely upon your own judgment rather than upon any other man's judgment.

The numerous agents of land and railroad companies, and the officials of the various governments, have in their power to make a man, looking for a location, very comfortable, by free rides, free lunches and numerous hospitalities, which induce a man to be satisfied with his surroundings.

TABLE No. 1.

Velocity in feet per second of Water in farm-drains flowing full, with the following falls.

Fall.	Inside Diameter of Pipe in Inches.												
	2	3	4	5	6	7	8	9	10	12	15	18	21	24
1 in 5,000 ..	.26	.32	.37	.41	.45	.48	.52	.55	.58	.63	.71	.77	.84	.89
1 " 4,000 ..	.28	.35	.42	.46	.50	.54	.57	.61	.64	.71	.79	.87	.93	1.00
1 " 3,000 ..	.33	.40	.47	.52	.58	.62	.66	.71	.74	.81	.83	1.00	1.03	1.15
1 " 2,000 ..	.41	.50	.57	.64	.71	.76	.82	.87	.91	1.00	1.12	1.22	1.32	1.41
1 " 1,000 ..	.58	.71	.82	.91	1.00	1.08	1.15	1.22	1.29	1.41	1.58	1.73	1.87	2.00
1 " 900 ..	.61	.75	.86	.97	1.06	1.13	1.22	1.29	1.36	1.50	1.63	1.83	1.93	2.12
1 " 800 ..	.65	.79	.90	1.03	1.12	1.19	1.29	1,37	1.44	1.58	1.68	1.93	2.09	2.24
1 " 700 ..	.70	.84	.95	1.10	1.20	1.30	1.38	1.47	1.55	1.70	1.83	2.08	2.25	2,37
1 " 600 ..	.74	.91	1.00	1.18	1.29	1.39	1.48	1.58	1.66	1.83	1.98	2.23	2.39	2.50
1 " 500 ..	.81	1.00	1.15	1.29	1.41	1.53	1.63	1.73	1.83	2.00	2.20	2.45	2.64	2.83
1 " 450 ..	.85	1.05	1.22	1.35	1.50	1.60	1.70	1.83	1.95	2.11	2.35	2.60	2.80	3.00
1 " 400 ..	.91	1.11	1.29	1.44	1.58	1.70	1.81	1.93	2.04	2.23	2.50	2.74	2.95	3.16
1 " 350 ..	1.00	1.20	1.40	1.55	1.70	1.83	1.93	2.07	2.20	2.40	2.67	2.95	3.25	3.33
1 " 300 ..	1.10	1.29	1.50	1.65	1.82	1.97	2.06	2.20	2.35	2.55	2.88	3.15	3.58	3.61
1 " 250 ..	1.16	1.42	1.64	1.82	2.00	2.16	2.30	2.44	2.58	2.82	3.16	3.46	3.74	4.00
1 " 200 ..	1.30	1.58	1.81	2.06	2.23	2.39	2.58	2.73	2.88	3.16	3.36	3.87	4.18	4.47
1 " 150 ..	1.50	1.80	2.0[illegible]	2.35	2.57	2.75	2.95	3.15	3.30	3.65	3.95	4.39	4.68	5.00
1 " 100 ..	1.82	2.23	2.58	2.88	3.16	3.41	3.65	3.87	4.08	4.47	5.00	5.48	5.91	6.32
1 " 90 ..	1.92	2.36	2.72	3.05	3.34	3.60	3.86	4.10	4.32	4.72	5.29	5.8[illegible]	6.25	6.65
1 " 80 ..	2.03	2.50	2.87	3.22	3.53	3.81	4.08	4.33	4.56	5.00	5.59	6.1[illegible]	6.61	7.07
1 " 70 ..	2.18	2.67	3.10	3.47	3.80	4.10	4.40	4.70	4.95	5.40	5.75	6.60	7.10	7.75
1 " 60 ..	2.34	2.88	3.31	3.73	4.10	4.45	4.80	5.05	5.38	5.80	6.50	7.07	7.61	8.16
1 " 50 ..	2.60	3.16	3.62	4.12	4.47	4.79	5.16	5.47	5.75	6.32	7.07	7.74	8.36	8.94
1 " 40 ..	2.83	3.53	4.12	4.58	5.00	5.38	5.74	6.11	6.45	7.07	7.88	8.66	9.35	10.00
1 " 30 ..	3.45	4.04	4.75	5.25	5.77	6.24	6.65	7.07	7.45	8.15	8.26	10.00	10.30	11.54
1 " 20 ..	4.07	5.00	5.74	6.45	7.07	7.63	8.16	8.66	9.12	10.00	11.18	12.25	13.23	14.14
1 " 10 ..	5.77	7.07	8.18	9.12	10.00	10.81	11.54	12.25	12.92	14.14	15.81	17.32	18.71	20.00

TABLE No. 2.

Discharge in cubic feet per second of circular farm-drains flowing full, with the following falls.

FALL.	Inside Diameter of Pipe in Inches.													
	2	3	4	5	6	7	8	9	10	12	15	18	21	24
1 in 5,000 ..	.0058	.0016	.0320	.0560	.0880	.1280	.1810	.2430	.3160	.4940	.8670	1.360	2.020	2.800
1 " 4,000 ..	.0662	.0170	.0365	.0625	.0980	.1440	.1990	.2696	.3488	.5570	.9690	1.527	2.237	3.142
1 " 3,000 ..	.0074	.0198	.0410	.0710	.1130	.1670	.2220	.3120	.4060	.6390	1.013	1 760	2.480	3.630
1 " 2,000 ..	.0089	.0240	.0500	.0880	.1380	.2040	.2850	.3830	.4970	.7850	1.370	2.160	3.180	4.440
1 " 1,000 ..	.0126	.0340	.0720	.1240	.1960	.2886	.3980	.5400	.6980	1.110	1.910	3.050	4.470	6.280
1 " 900 ..	.0130	.0370	.0760	.1320	.2100	.3050	.4200	.5600	.7400	1.170	2.050	3.220	4.750	6.660
1 " 800 ..	.0140	.0400	.0800	.1400	.2200	.3200	.4500	.6100	.7900	1.230	2.170	3.400	5.050	7.000
1 " 700 ..	.0150	.0420	.0830	.1500	.2350	.3450	.4800	.6500	.8400	1.330	2.290	3.660	5.400	7.480
1 " 600 ..	.0160	.0450	.0870	.1600	.2500	.3700	.5200	.6980	.9000	1.440	2.420	3.940	5.750	7.850
1 " 500 ..	.0178	.0480	.1000	.1760	.2760	.4080	.5700	.7660	.9940	1.570	2.740	4.320	6.360	8.880
1 " 450 ..	.0190	.0510	.1060	.1850	.2890	.4300	.6000	.8000	1.050	1.690	2.900	4.570	6.730	9.400
1 " 400 ..	.9200	.0554	.1120	.1950	.3100	.4500	.6400	.8500	1.100	1.750	3.060	4.840	7.100	9.930
1 " 350 ..	.0220	.0590	.1210	.2100	.3300	.4900	.6700	.9100	1.200	1.880	3.280	5.210	7.820	10.620
1 " 300 ..	.0230	.0630	.1320	.2300	.3600	.5300	.7200	.9900	1.280	2.050	3.530	5.550	8.600	11.350
1 " 250 ..	.0250	.0680	.1440	.2480	.3920	.5760	.7960	1.080	1.396	2.220	3.880	6.100	8.940	12.560
1 " 200 ..	.0300	.0800	.1600	.2800	.4400	.6400	.9000	1.210	1.580	2.470	4.330	6.800	10.000	14.000
1 " 150 ..	.0330	.0900	.1740	.3200	.5000	.7400	1.040	1.390	1.850	2.880	4.840	7.880	11.500	15.700
1 " 100 ..	.0400	.1090	.2240	.3900	.6200	.9100	1.270	1.710	2.220	3.510	6.130	9.680	14.210	19.860
1 " 90 ..	.0420	.1150	.2400	.4100	.6500	.9600	1.350	1.820	2.350	3.700	6.500	10.250	15.050	21.000
1 " 80 ..	.0450	.1220	.2500	.4400	.6900	1.020	1.430	1.920	2.480	3.920	6.860	10.820	15.910	22.220
1 " 70 ..	.0510	.1300	.2700	.4700	.7400	1.09	1.530	2.08	2.690	4.24	7.050	11.660	17.070	23.720
1 " 60 ..	.0540	.1400	.2900	.5100	.8000	1.17	1.660	2.23	2.930	4.55	8.070	12.490	18.300	25.640
1 " 50 ..	.0570	.1600	.3200	.5600	.8800	1.28	1.810	2.43	3.160	4.94	8.670	13.600	20.200	28.000
1 " 40 ..	.0630	.1700	.3600	.6200	.9800	1.44	1.990	2 70	3.490	5.57	9.690	15.270	22.370	31.420
1 " 30 ..	.0740	.1980	.4100	.7100	1.130	1,67	2.220	3.12	4.160	6.40	10.130	17.670	24.770	36.260
1 " 20 ..	.0890	.2450	.5000	.8800	1.380	2.04	2.850	3.83	4.970	7.85	13.720	21.640	31.820	44.430
1 " 10 ..	.1260	.3400	.7200	1.240	1.960	2.88	3.980	5.40	6.980	11.14	19 380	30.540	44.740	62.840

TABLE No. 3.

Number of acres of farm-lands drained by circular tile underdrains flowing full, with the following falls. Rainfall 20 inches per annum.

FALL.	Inside diameter of pipe in inches.													
	2	3	4	5	6	7	8	9	10	12	15	18	21	24
1 in 5,000 ..	2.0	5.7	11.5	20.0	31.5	45.7	65.0	86.7	112.7	176.0	310.0	485.0	721.0	1000.0
1 " 4,000 ..	2.2	6.0	13.0	22.0	35.0	51.0	71.0	96.0	125.0	199.0	346.0	545.0	799.0	1122.0
1 " 3,000 ..	2.6	7.0	14.6	25.0	40.0	60.0	79.0	111.0	145.0	228.0	362.0	631.0	885.0	1249.0
1 " 2,000 ..	3.2	8.7	18.0	31.0	49.0	73.0	102.0	137.0	177.0	280.0	490.0	773.0	1136.0	1587.0
1 " 1,000 ..	4.5	12.0	26.0	44.0	70.0	103.0	142.0	193.0	249.0	398.0	692.0	1091.0	1598.0	2244.0
1 " 900 ..	4.7	13-0	27.0	47.0	75.0	108.0	151.0	203.0	264 0	417.0	730.0	1152.0	1669.0	2364.0
1 " 800 ..	5.0	14.0	28.0	50.0	78.0	114.0	162.0	216 0	282.0	441.0	775.0	1214.0	1803.0	2500.0
1 " 700 ..	5.2	15 0	30.0	53.0	84.0	125.0	175.0	232.0	300.0	475.0	817.0	1307.0	1927.0	2650.0
1 " 600 ..	5.8	16.2	31.2	57.0	89.0	132.0	186.0	248.0	325.0	514.0	864.0	1408.0	2053.0	2804.0
1 " 500 ..	6.4	17.4	36.0	62.0	98.0	146.0	204.0	274.0	354.0	560.0	980.0	1546.0	2272.0	3174.0
1 " 450 ..	6.7	19.0	38.0	67.0	105.0	152.0	217.0	289.0	376.0	588.0	1033.0	1619.0	2405.0	3333.0
1 " 400 ..	7.0	19.2	40.0	70.0	112,0	162.0	226.0	305.0	396.0	629.0	1095.0	1728.0	2503.0	3586.0
1 " 350 ..	7.8	21.0	43.0	75.0	117.0	175.0	240.0	325.0	427.0	672.0	1172.0	1860.0	2792.0	3792.0
1 " 300 ..	8.3	22.0	47.0	62.0	127.0	190.0	257.0	352.0	457.0	732.0	1260.0	1982.0	3072.0	4052.0
1 " 250 ..	9.0	24.0	52.0	88.0	140.0	206.0	284.0	386.0	498.0	796.0	1384.0	2182.0	3196.0	4488.0
1 " 200 ..	10.1	28.0	57.0	100.0	157.0	228.0	325.0	433.0	563.0	882.0	1550.0	2428.0	3607.0	5000.2
1 " 150 ..	11.7	32.5	62.0	115.0	178.0	265.0	372.0	497.0	650.0	1028.0	1728.0	2815.0	4107.0	5607.0
1 " 100 ..	14.0	39.0	80.0	140.0	225.0	325.0	432.0	610.0	729.0	1252.0	2190.0	3457.0	5007.0	7092.0
1 " 90 ..	15.0	41.0	86.0	144,0	233.0	342.0	474.0	642.0	831.0	1326.0	2387.0	3636.0	5327.0	7481.0
1 " 80 ..	15.8	43.0	88.0	157.0	246.0	363.0	508.0	683.0	887.0	1401.0	2450.0	3863.0	5682.0	7934.0
1 " 70 ..	18.0	47.0	97.0	167.0	265.0	390.0	547.0	742.0	960.0	1515.0	2517.0	4165.0	6097.0	8475.0
1 " 60 ..	19-0	50.0	102-0	182.0	285.0	417.0	592.0	797.0	1017.0	1625.0	2882.0	4460.0	6535.0	9157.0
1 " 50 ..	20.2	57.0	115.0	200.0	315.0	457.0	650.0	867.0	1127.0	1765.0	3100.0	4857.0	7215.0	10000.0
1 " 40 ..	22.5	60.7	128-0	222.0	350.0	515.0	710.0	965.0	1247.0	1990.0	3460.0	5452.0	7990.0	11225.0
1 " 30 ..	26.5	70.7	146.5	253.0	403.0	600.0	792.0	1115.0	1450.0	2285.0	3617.0	6310.0	8850.0	12495.0
1 " 20 ..	31.7	87.0	177.0	315.0	492.0	727.0	1017.0	1367.0	1775.0	2802.0	4900.0	7727.0	11365.0	15868.0
1 " 10 ..	45.0	122.0	257.0	442.0	700.0	1027.0	1422.0	1927.0	2492.0	3977.0	6922.0	10907.0	15980.0	22442.0

TABLE No. 4.

Number of acres of farm-lands drained by circular tile underdrains flowing full, with the following falls. Rainfall 30 inches per annum.

Fall.	Inside diameter of pipe in inches.												
	2	3	4	5	6	7	8	9	10	12	15	18	21	24
1 in 5,000 ..	1.3	3.8	7.7	13.3	21.0	30.5	43.3	57.8	75.1	117.7	206.7	323.0	480.1	666.7
1 " 4,000 ..	1.5	4.0	8.7	15.0	23.3	34.3	47.3	64.2	83.0	132.7	230.7	363.3	531.7	748.3
1 " 3,000 ..	1.8	4.7	9.8	16.7	26.7	40.0	53.4	75.0	96.7	152.4	241.8	420.0	590.0	863.3
1 " 2,000 ..	2.1	5.8	11.8	21.7	33.4	50.0	66.7	91.7	118.7	186.0	326.7	515.0	756.7	1058.3
1 " 1,000 ..	3.0	8.3	16.7	30.0	46.7	68.3	95.0	128.3	166.7	265.0	461.7	726.7	1065.1	1496.1
1 " 900 ..	3.2	8.8	18.1	31.7	50.0	71.7	100.0	133.4	176.7	273.3	488.3	766.7	1113.4	1577.0
1 " 800 ..	3.3	9.7	19.1	33.3	52.5	76.3	108.4	144.5	188.3	295.0	516.6	810.0	1203.4	1666.7
1 " 700 ..	3.5	10.0	19.8	35.7	56.0	83.4	116.7	155.0	200.0	316.7	545.0	871.7	1285.0	1766.7
1 " 600 ..	3.8	10.7	20.7	38.3	60.0	88.3	123.4	166.1	216.7	343.4	576.4	938.4	1368.3	1868.3
1 " 500 ..	4.2	11.6	23.6	43.4	66.8	100.0	133.4	183.4	237.0	372.0	652.0	1030.0	1513.0	2117.0
1 " 450 ..	4.5	12.1	25.1	44.0	68.9	101.7	143.0	190.0	250.0	401.0	690.0	1090.0	1601.0	2238.0
1 " 400 ..	4.7	13.2	27.0	47.5	75.0	107.5	150.0	200.0	265.0	418.0	732.0	1150.0	1617.0	2365.0
1 " 350 ..	5.2	14.0	28.9	50.0	78.3	116.7	160.0	216.7	285.0	444.3	781.6	1240.0	1861.0	2528.0
1 " 300 ..	5.5	15.0	31.7	55.0	85.0	127.0	171.0	235.0	305.0	489.0	840.0	1321.0	2049.0	2701.0
1 " 250 ..	6.0	16.7	33.4	60.0	93.0	136.7	190.0	257.0	333.0	530.0	923.0	1453.0	2130.0	2992.0
1 " 200 ..	6.7	19.4	38.2	66.7	105.0	152.7	217.0	289.0	377.0	590.0	1033.0	1620.0	2407.0	3333.4
1 " 150 ..	7.6	21.4	41.4	76.7	120.0	177.6	247.0	332.0	433.0	687.0	1153.0	1877.0	2737.0	3737.0
1 " 100 ..	9.5	26.4	54.3	95.1	150.0	215.1	300.0	400.2	530.1	835.9	1465.0	2300.0	3340.0	4731.0
1 " 90 ..	10.0	27.0	57.0	100.0	155.0	234.0	317.0	434.0	553.0	883.0	1539.0	2433.0	3550.0	5090.0
1 " 80 ..	10.5	29.0	59.0	108.5	167.0	250.0	333.5	458.5	591.5	930.0	1634.0	2575.0	3783.0	5291.0
1 " 70 ..	12.1	31.7	65.0	111.7	177.0	260.0	365.0	495.0	640.0	1010.0	1679.0	2777.0	4065.0	5650.0
1 " 60 ..	12.8	33.4	68.0	121.7	190.0	278.0	395.0	531.7	698.0	1083.0	1921.0	2973.0	4357.0	6105.0
1 " 50 ..	13.5	38.0	77.0	133.0	210.0	305.0	433.0	578.0	751.0	1177.0	2067.0	3239.0	4801.0	6667.0
1 " 40 ..	15.0	40.0	87.0	150.0	233.0	343.0	473.0	642.0	830.0	1327.0	2307.0	3633.0	5317.0	7483.0
1 " 30 ..	18.0	47.0	97.7	167.0	267.0	400.0	534.0	750.0	967.0	1524.0	2418.0	4200.0	5900.0	8633.0
1 " 20 ..	21.0	58.0	118.0	217.0	334.0	500.0	667.0	917.0	1183.0	1860.0	3269.0	5150.0	7567.0	10583.0
1 " 10 ..	30.0	83.0	167.0	300.0	467.0	613.0	950.0	1283.0	1667.0	2650.0	4617.0	7267.0	10651.0	14961.0

TABLE No. 5.

Number of acres of farm lands drained by circular tile underdrains flowing full, with the following falls. Rainfall 40 inches per annum.

Fall.	Inside diameter of pipe in inches.													
	2	3	4	5	6	7	8	9	10	12	15	18	21	24
1 in 5,000 ..	1.0	3.0	6.0	10.0	16.0	23.0	32.0	43.0	56.0	88.0	155.0	243.0	360.0	506.0
1 " 4,000 ..	1.1	3.1	6.5	11.0	17.0	25.0	35.0	48.0	62.0	100.0	170.0	272.0	400.0	561.0
1 " 3,000 ..	1.3	3.5	7.3	12.0	20.0	30.0	40.0	56.0	72.0	114.0	180.0	302.0	442.0	647.0
1 " 2,000 ..	1.6	4.4	9.0	16.0	25.0	36.0	51.0	68.0	90.0	140.0	245.0	390.0	568.0	800.0
1 " 1,000 ..	2.2	6.0	13.0	22.0	35.0	51.0	70.0	96.0	124.0	200.0	345.0	545.0	800.0	1120.0
1 " 900 ..	2.4	7.0	13.6	24.0	38.0	54.0	75.0	100.0	132.0	209.0	357.0	575.0	850.0	1190.0
1 " 800 ..	2.5	7.2	14.2	25.0	40.0	57.0	81.0	108.0	141.0	221.0	388.0	607.0	902.0	1250.0
1 " 700 ..	2.6	7.5	15.0	26.7	42.0	62.6	90.0	117.0	150.0	237.0	409.0	654.0	964.0	1325.0
1 " 600 ..	2.9	8.0	15.5	29.0	45.0	66.0	92.0	125.0	162.0	257.0	432.0	703.0	10.260	1402.0
1 " 500 ..	3.1	9.0	18.0	32.0	50.0	72.0	101.0	136.0	178.0	281.0	490.0	771.0	1136.0	1590.0
1 " 450 ..	3.4	9.1	19.0	33.0	51.0	75.0	107.0	142.0	187.0	302.0	517.0	816.0	1202.0	1679.0
1 " 400 ..	3.6	10.0	20.0	35.0	55.0	81.0	114.0	152.0	199.0	312.0	547.0	863.0	1269.0	1774.0
1 " 350 ..	3.9	10.5	21.6	37.5	59.0	88.0	120.0	162.0	213.0	346.0	586.0	930.0	1306.0	1896.0
1 " 300 ..	4.1	11.2	24.0	41.0	64.0	95.0	129.0	175.0	221.0	366.0	630.0	991.0	1336.0	2026.0
1 " 250 ..	4.5	12.1	25.0	44.0	70.0	102.0	142.0	192.0	249.0	396.0	692.0	1089.0	1596.0	2242.0
1 " 200 ..	5.0	14.4	28.7	50.0	78.5	114.0	162.0	217.0	282.0	441.0	775.0	1217.0	1804.0	2500.0
1 " 150 ..	6.0	16.2	32.0	57.0	90.0	132.0	186.0	249.0	325.0	514.0	864.0	1475.0	2054.0	2838.0
1 " 100 ..	7.1	19.5	40.0	70.0	112.0	162.0	226.0	305.0	396.0	626.0	1095.0	1729.0	2538.0	3546.0
1 " 90 ..	7.5	20.5	42.5	75.0	116.0	171.0	237.0	321.0	415.0	663.0	1153.0	1818.0	2663.0	3740.0
1 " 80 ..	8.0	21.7	45.0	79.0	124.0	182.0	255.0	342.0	444.0	700.0	1225.0	1932.0	2842.0	3969.0
1 " 70 ..	9.0	23.7	49.0	84.0	132.0	195.0	261.0	371.0	480.0	757.0	1259.0	2082.0	3049.0	4238.0
1 " 60 ..	9.6	25.0	51.0	91.0	142.0	209.0	296.0	399.0	524.0	812.0	1441.0	2230.0	3257.0	4579.0
1 " 50 ..	10.1	29.0	57.5	100.0	158.0	229.0	325.0	434.0	569.0	882.0	1550.0	2429.0	3607.0	5000.0
1 " 40 ..	11.5	30.0	64.0	111.0	175.0	257.0	355.0	482.0	623.0	995.0	1730.0	2726.0	3995.0	5616.0
1 " 30 ..	13.0	35.0	73.0	117.0	202.0	300.0	396.0	557.0	725.0	1142.0	1809.0	3155.0	4425.0	6475.0
1 " 20 ..	16.0	44.0	90.0	157.0	246.0	364.0	509.0	684.0	887.0	1401.0	2550.0	3864.0	5682.0	7934.0
1 " 10 ..	22.0	61.0	130.0	221.0	350.0	514.0	711.0	964.0	1246.0	1990.0	3461.0	5454.0	7990.0	11221.0

TABLE No. 6.

Number of acres of farm-lands drained by circular tile underdrains flowing full, with the following falls. Rainfall 59 inches per annum.

Fall.	Inside diameter of pipe in inches.												
	2	3	4	5	6	7	8	9	10	12	15	18	21	24
1 in 5,000 ..	0.8	2.3	4.6	8.0	12,6	18.3	26.0	34.7	45.1	70.6	124.0	194.0	288.6	400.0
1 " 4,000 ..	0.9	3.4	5.2	9.0	14.0	20.6	28.4	38.5	49.8	79.6	238.4	218.0	319.0	449.0
1 " 3,000 ..	1.1	2.8	5.9	10.1	16.0	24.0	32.0	45.0	58.0	91.4	135.1	252.0	334.0	518.0
1 " 2,000 ..	1.3	3.5	7.1	13.0	20,0	30.0	40.0	55.0	71.0	111.0	106.3	908.0	454.9	655.0
1 " 1,000 ..	1.8	5.0	10.0	18.0	28.0	41.0	57.0	77.0	100.0	159.0	277.0	436.0	639.0	897.0
1 " 900 ..	1.9	5.3	10.9	18.0	30.0	43.0	60.0	80.0	106.0	167.0	292.0	460.0	668.0	946.0
1 " 800 ..	2.0	5.8	11.5	20.0	31.5	46.0	65.0	87.0	113.0	177.0	110.0	486.0	722.0	1000.0
1 " 700 ..	2.1	6.0	11.9	21.4	34.0	50.0	70.0	93.0	120.0	190.0	327.0	523.0	771.0	1060.0
1 " 600 ..	2.3	6.4	15.4	23.0	36.0	53.0	74.0	100.0	130.0	206.0	346.0	563.0	821.0	1121.0
1 " 500 ..	2.5	7.0	14.3	25.0	39.0	58.0	81.0	109.0	142.0	224.0	391,0	617.0	809.0	1270.0
1 " 450 ..	2.7	7.3	15.1	16.4	41.0	61.0	86.0	114.0	150.0	241.0	414.0	553.0	961.0	13e3.0
1 " 400 ..	2.9	7.9	16.0	28.0	44.0	65.0	91.0	122.0	159.0	250.0	438.0	691.0	1001.0	1319.0
1 " 350 ..	3.1	8.4	17.3	30.0	47.0	80.0	96.0	130.0	171.0	369.0	469.0	744.0	1117.0	1517.0
1 " 300 ..	3.3	9.0	19.0	33.0	51.0	76.0	103.0	141.0	183.0	293.0	501.0	793.0	1229.0	1621.0
1 " 250 ..	3.6	9.8	20.6	35.0	56.0	82.0	114.0	154.0	198.0	317.0	554.0	871.0	1267.0	1794.4
1 " 200 ..	4.0	11.5	23.0	40.0	63.0	91.0	130.9	173.0	226.0	353.0	620,0	972.0	1443.0	2000.0
1 " 150 ..	4.7	13.0	25.0	46.0	71.0	106.0	149.0	195.0	260.0	411.0	691.0	1216.0	1643.0	2243.3
1 " 100 ..	5.7	15.6	32.0	56.0	90.0	130.0	181.0	244.0	317.0	501.0	876.0	1383.0	2003.0	2837.0
1 " 96 ..	6.0	16.4	34.0	60.0	93.0	140.0	180.0	260.0	332.0	530.0	923.0	1454.0	2130.0	3000.0
1 " 80 ..	6.4	17.4	36.0	63.0	99.0	146.0	204.0	274.0	355.0	560.0	980.0	1546.0	2273.0	3174.0
1 " 70 ..	7.3	19.0	39.0	67.0	106.0	156.0	219.0	297.0	381.0	606.0	1007.0	1666.0	2439.0	3390.0
1 " 60 ..	7.7	20.0	44.0	73.0	114.0	167.8	237.0	318.0	419.0	650.0	1153.0	2784.4	2614.0	3660.0
1 " 50 ..	8.1	23.0	46.0	80.0	126.7	183.0	260.0	347.0	451.0	706.0	1140.0	1943.0	2886.0	4000.0
1 " 40 ..	8.0	24.0	51.0	89.0	140.0	206.0	284.2	386.0	499.0	796.0	1381.0	2181.0	3196.0	4490.0
1 " 30 ..	10.6	28.0	58.0	161.0	161.0	240.0	317.0	446.0	580.0	914.0	1447.0	2524.0	3540.0	5180.0
1 " 20 ..	12.7	36.0	71.0	126.0	197.0	271.0	407.0	547.0	710.0	1121.0	1960.0	3891.0	4546.0	6347.0
1 " 10 ..	18.0	49.0	177.0	177.0	280.0	411.0	559.0	771.0	997.0	1501.0	2769.0	4363.0	6391.0	8977.0

Our attention was drawn in 1884, to the matter of draining the prairies of the North-west. While in Winnipeg in charge of extensive drainage works, the question was often asked, "How are we to drain these prairies?" The real difficulty is, apparently, that the frost penetrates the soil to the great depth of over eight feet. We found the average frost-line over eight feet below the surface. From repeated observations since that time, there appears to be no doubt that deep drains, down below the frost-line, would completely drain this very rich clay-loam. As deep drainage promotes the aeration and disintegration of the soil to a far greater extent than is generally believed by most people, we would propose that land in Manitoba, the North-west Territories, Dakota, etc., be drained at nine feet deep, and at 150 feet apart, between the drains. This would give the water an inclination of 1 in 8 to fall each way into the drains, and leave over a foot of drained land in the middle between the drains. So that the drainage of these extensive rich lands could be done, perhaps, cheaper than any other tract of land of similar extent, richness and fertility on the continent. The absence of stones rendering machinery for cutting trenches serviceable, and the comparatively small number of drain trenches to dig, would more than counterbalance the greater cost of deeper trenches.

The outlets would have to be into the Red, Assiniboine, Saskatchewan, and similar rivers, where plenty of sites can be found.

It is recommended that the method of locating the drains be nearly the same as is illustrated in page 10, diagram No. 1, with the drains, of course, 150 feet instead of 80 feet between them.

The main drain could be carried back from the river many miles; as, by using a large pipe, very little fall would suffice to give the water a steady flow towards the river. The river banks are eminently suited for outlets; as, during the summer, the water in the rivers is very low,—in some cases over 40 feet below the general level of the prairie. The possible objection that the soil is too

stiff to admit of water percolating through it, will be found in practice to be not well founded; because the water held in the soil must, at some time during the summer, find its way into the drain; and the water does not all sink down, but comes up, and from the sides as well.

To prove this, let a man about August dig a hole on the prairie a few feet in depth, and, if the land wants drainage, water will come into it from all sides and up from the bottom.

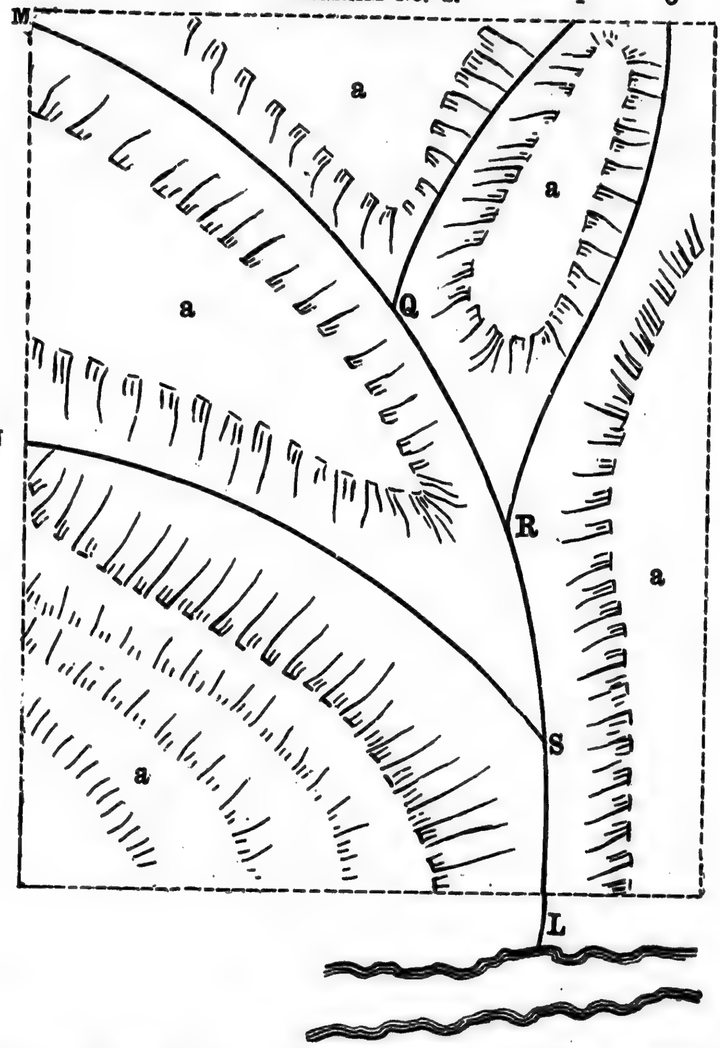
Drainage promotes porosity, so that drained land is affected in a less degree by extremes of cold and heat. The soil is warmer in winter, and less affected by drought in summer. The thing to be attained by drainage is to aerate and pulverize the subsoil by the action of the weather; and it is certain that the frost will not penetrate to so great a depth in drained as in undrained lands.

Surface ditches are of very little benefit, because, if the subsoil be dry, land cannot be much hurt by surface water. It is only an evidence that the subsoil wants draining when there is standing water on land.

The distance apart we have mentioned for the drains will suit only some sorts of soil. When the soil is of a more compact mass, the distances apart for the draining must be closer than 150 feet, even though we must dig 9 feet deep to get below the frost-line. There is much land in Dakota, and the North-west Territories generally, where the frost does not penetrate the soil 8 feet. The drains must be arranged accordingly.

Though there is not much land anywhere but would receive benefit from drainage, it does not follow that it would be expedient to drain it in all cases. If a farmer has a hilly farm where there are elevated ridges, and low, wet valleys, true economy would indicate that the low, wet valleys should be drained only. The plan of drainage for this sort of a farm is illustrated by Diagram No. 2, as above. Let the space enclosed by the dotted line represent a farm of 100 acres. Then the black lines L S R Q M, S N, R O, and Q P, represent drains having a common outlet at L, into the stream, and aaaaa hills. It must

DIAGRAM No. 2.



be borne in mind that the portion of the drain from L S must be large enough to carry all the water due to the hundred acres. For instance, if the rainfall is 40 inches (See table No. 5), and the general inclination or fall of the drains 1 in 200, then the drain tile must be 7 inches in diameter from L to S, for table No. 5 gives us 114.4 as the number of acres that a 7-inch tile will drain. This

is a little large, for reasons before explained herein. All the drains must be proportioned accordingly; for the water which falls in the shape of rain and snow on the hills or elevated ridges aaaaa, must find its way somewhere. It will most likely percolate through the soil down to the valleys and come up in the shape of springs there, unless drains are provided to receive it.

Estimate of Cost.

L S=100 acres=700 lineal ft.	7-inch pipe, @ $5\frac{1}{2}$c. =	$38	50.
S R= 70 acres=700 "	6-inch pipe, @ 4 c. =	28	00.
S N=minor drains 2100 "	3-inch pipe, @ $1\frac{1}{4}$c. =	26	25.
R Q=700 "	3-inch pipe, @ $1\frac{1}{4}$c. =	8	75.
R O=2300 "	3-inch pipe, @ $1\frac{1}{4}$c. =	28	75.
Q P=1400 "	3-inch pipe, @ $1\frac{1}{4}$c. =	17	50.
Q M=1750 "	3-inch pipe, @ $1\frac{1}{4}$c. =	21	87.
		$169	62
Digging, laying, etc.		482	50
Total cost		$652	12

or, say an average cost $6.52 per acre for the 100 acres No matter what the size of the farm may be, provide drains for the low, wet valleys, and the ridges or hills in most cases will drain themselves if provision is made in the size of the drains for the total acreage. This applies to pretty steep hills that are cultivated. But stiff clay hills, if cultivated, would be better if thoroughly drained.

The question of deep drainage is not new. As long ago as the 17th century, Captain Blith of England wrote—"Whenever you see draining and trenching you shall rarely find any of them wrought to the bottom. But for these common and many trenches, oftentimes crooked, too, that men usually make in their boggy grounds, some one foot, some two, I say away with them as a great piece of folly, lost labor, and spoil. And for the draining trench it must be made so deep that it go to the bottom of the cold, spewing moist water that feeds the flag and the rush * * * * * A yard or four feet deep, if ever thou wilt drain to any purpose. To the bottom where the spewing

spring lieth thou must go, and one spade's graft beneath, how deep soever it be, if thou wilt drain thy land to purpose." There seems to be a *consensus* of opinion among all practical agriculturists who have tried drainage to a sufficient depth, that it will increase the products of the soil from 25 per cent. to 50 per cent., and that drains are generally put down too shallow.

Without good drainage it is useless to hope for better times among farmers. In the North and North-west where the rigors of winter, and sometimes the droughts of summer, are felt, there is no doubt the effects of drainage on a large scale would ameliorate the climate in winter, and the soil would retain its moisture in summer to a much greater extent; because thoroughly drained land is not only of higher temperature, or warmer, in cold weather, but it holds its moisture longer in drought, which generally occurs when evaporation is rapid during summer. It is not uncommon to find the soil light and porous on the surface, but the subsoil impervious, and a soil thus constituted is literally baked under a hot sun. A sure indication of impervious subsoil is the growth of aquatic plants in places where the land is so situated that from general indications they should not be there.

When walking over pastures in summer-time, after a rain, we feel the land spongy instead of springy to the feet, that land wants drainage. It has a subsoil composed of clay, hard-pan, or other impervious substance, and will be, in either dry or wet weather, next to useless. Such land can never be made under any system of cultivation, manuring or other operation, fit for husbandry without thorough drainage.

As a prominent professor of agriculture says, "I don't believe farming can be pursued with profit without draining."

The following clear statement on the fitness of soil for the promotion of the germination of plants is taken from a valuable lecture on Agricultural Science, by Dr. Madden of England, and is quoted by the General Board of Health in their "Minutes of Information." It is the clearest exposition that we have met.

"The first thing which occurs, after the sowing of the seed is, of course, germination; and before we examine how this process may be influenced by the condition of the soil, we must necessarily obtain some correct idea of the process itself. The most careful examination has proved that the process of germination consists essentially of various chemical changes, which require for their development the presence of air, moisture, and a certain degree of warmth. Now, it is obviously unnecessary for our present purpose that we should have the least idea of the nature of these processes. All we require to do, is to ascertain the conditions under which they take place; having detected these, we know at once what is required to make a seed grow. These we have seen are air, moisture and a certain degree of warmth; and it consequently results that whenever a seed is placed in these circumstances, germination will take place. Viewing matters in this light, it appears that soil does not act chemically in the process of germination; that its sole action is confined to its being the vehicle by means of which a supply of air and moisture and warmth can be continually kept up. With this simple statement in view, we are quite prepared to consider the various conditions of soil, for the purpose of determining how far these will influence the future prospects of the crop, and we shall accordingly at once proceed to examine carefully into the mechanical relations of soil.

"Soil, examined mechanically, is found to consist entirely of particles of all shapes and sizes, from stones and pebbles down to the finest powder; and on account of their extreme irregularity of shape, they cannot be so close to one another as to prevent there being passages between them, owing to which circumstances, soil in the mass is always more or less porous. If, however, we proceed to examine one of the smallest particles of which soil is made up, we shall find that even this is not always solid, but is much more frequently porous, like soil in the mass. A considerable portion of this finely divided part of soil, the impalpable matter, as it is generally called, is

found by the aid of the microscope, to consist of broken-down vegitable tissue, so that when a small portion of the finest dust from a garden or field is placed under the microscope, we have exhibited to us particles of every variety of shape and structure, of which a certain part is evidently of vegetable origin.

"On examining a perfectly dry soil, we perceive there are two distinct classes of pores: 1st, the large ones, which exist between the particles of soil, and 2nd, the minute ones, which occur in the particles themselves; and whereas all the larger pores—those between the particles of soil—communicate most freely with each other, so that they form canals, the small pores, however freely they may communicate with one another in the interior of the particle in which they occur, have no direct communication with the pores of the surrounding particles. Let us now, therefore, trace the effect of this arrangement. If the soil is perfectly dry, the canals communicating freely at the surface with the surrounding atmosphere, the whole of these canals and pores will, of course, be filled with air. If, in this condition, a seed be placed in the soil you at once perceive that it is freely supplied with air, but there is no moisture; therefore, when soil is perfectly dry a seed cannot grow.

"Let us turn our attention now to that state of the soil in which water has taken the place of air, or, in other words, the soil is very wet. If we observe our seed now, we find it abundantly supplied with water, but no air. Here again, therefore, germination cannot take place. It may be well to state here that this can never occur exactly in nature, because water having the power of dissolving air to a certain extent, the seed is, in fact, supplied with a certain amount of this necessary substance, and owing to this, germination does take place, although by no means under such advantageous circumstances as it would were the soil in a better condition.

"We pass on now to a different state of matters. Let us suppose the canals are open and freely supplied with air, while the pores are filled with water. While the seed

now has quite enough of air from the canals, it can never be without moisture, as every particle of soil which touches it is well supplied with this necessary. This, then, is the proper condition of soil for germination, and in fact, for every period for the plant's development; and this condition occurs when the soil is moist but not wet—that is to say, when it has the color and appearance of being well watered, but when it is still capable of being crumbled to pieces by the hands, without any of its particles adhering together in the familiar form of mud.

"Let us observe still another condition of soil; in this instance as far as water is concerned, the soil is in its healthy condition—it is moist but not wet, the pores alone being filled with water. But where are the canals? We see them in a few places, but in by far the greater part of the soil none are to be perceived; this is owing to the particles of soil having adhered together, and thus so far obliterated the interstitial canals that they appear only like pores. This is the state of matters in every clod of earth, and you will at once perceive on comparing it with stone, that it differs from it only in possessing a few pores, which later, while they may form a reservoir for moisture, can never act as vehicles for the food of plants, as the roots are not capable of extending their fibres into the interior of a clod, but are at all times confined to the interstitial canals.

"With these four conditions before us, let us endeavor to apply them practically to ascertain where they occur in our fields, and how those which are injurious may be obviated.

"The first of them, we perceive, is a state of too great dryness, a very rare condition, in this climate at least; in fact, the only case in which it is likely to occur is in very coarse sands, where the soil, being chiefly made up of pure sand and particles of flinty matter, contains comparatively much fewer pores, and from the large size of the individual particles, assisted by their irregularity, the canals are wider, the circulation of air freer, and, consequently, the whole is much more easily dried. When this

state of matters exists, the best treatment is to leave all the stones which occur in the surface of the field, as they cast shades, and thereby prevent or retard the evaporation of water.

"We will not, however, make any further observations on this very rare case, but will rather proceed to a much more frequent, and in every respect more important, condition of the soil, an excess of water.

"When water is added to perfectly dry soil, it of course in the first instance, fills the interstitial canals, and from these enters the pores of each particle; and, if the supply of water be not too great, the canals speedily become empty, so that the whole of the fluid is taken up by the pores; this, we have already seen, is the healthy condition of the soil. If, however, the supply of water be too great, as in the case when a spring gains admission into the soil, or when the sinking of the fluid through the canals to a sufficient depth below the surface is prevented, it is clear that these also must get filled with water so soon as the pores have become saturated. This, then, is the condition of undrained soil.

"Not only are the pores filled, but the interstitial canals are likewise full, and the consequence is that the whole process of germination and growth of vegetables is materially interfered with. We shall here, therefore, briefly state the injurious effects of an excess of water, for the purpose of impressing more strongly upon your minds the necessity of thorough draining, as the first and most essential step towards the improvement of your soil.

"The first great effect of an excess of water is, that it produces a corresponding diminution of the amount of air beneath the surface, which air is of the greatest possible consequence in the nutrition of plants; in fact, if entirely excluded, germination could not take place, and the seed sown would, of course, either decay or lie dormant.

"Secondly, an excess of water is most hurtful, by reducing considerably the temperature of the soil; this I find by careful experiment to be to the extent of 6½ degrees Fahrenheit in summer, which amount is equiva-

lent to an elevation above the level of the sea of 1950 feet. So that, supposing two fields lying side by side, the one drained, the other undrained, and supposing them both equally well cultivated, there will be nearly as much difference in the amount and value of their respective crops, as if the drained one was situated at the level of the sea, and the other had an elevation as high as the most lofty of the Pentland hills.

"These are the chief injuries of an excess of water in soil which affect the soil itself. There are very many others affecting the climate, etc.; but these are not so connected with the subject in hand as to call for an explanation here.

"Of course all these injurious effects are at once overcome by thorough draining, the result of which is to establish a direct communication between the interstitial canals and the drains, by which means it follows that no water can remain any length of time in these canals withont, by its gravitation, finding its way into the drains.

"Too much cannot be said in favor of pulverizing the soil; even thorough draining itself will not supersede the necessity of performing this most necessary operation. The whole valuable effects of plowing, harrowing, grubbing, etc., may be reduced to this; and almost the whole superiority of garden over field produce is referable to the greater perfection to which this pulverizing of the soil can be carried. The celebrated Jethro Tull has the honor of having first directed the farmer's attention forcibly to this subject; and so deeply impressed was he with its infinite importance, that he believed the use of manure could be entirely superseded were this pulverizing carried to a sufficient extent.

"The whole success of drill husbandy is owing, in a great measure, to its enabling you to stir up the soil well during the progress of your crop; which stirring up is of no value beyond its effect in more minutely pulverizing the soil, increasing, as far as possible, the size and number of the interstitial canals.

"Lest anyone should suppose the contents of these interstitial canals must be so minute that their whole

amount can be of but little consequence, I may here notice the fact, that in moderately well pulverized soil, they amount to no less than one-fourth of the whole bulk of the soil itself. A familiar illustration of the space occupied by the spaces between the particles of loosened soil is afforded by the fact that when soil is disturbed it more than fills the space it previously occupied.

"Taking into calculation the weight of soil, we shall find that with every additional inch which you reduce to powder (by ploughing, for example, 9 inches in place of 8) you call into activity 235 tons of soil per acre, and render it capable of retaining beneath its surface 1,568,160 additional cubic inches of air; and, to take one more element into the calculation, supposing the soil were not properly drained, the sufficient pulverizing of an additional inch in depth would increase the escape of water from the surface by upwards of 100 gallons per day."

(The pulverizing of land could hardly be carried on, practicably, in undrained wet land, because every farmer knows that hard, tough clods, the natural outcome of wet, undrained soil, are only pulverized with much labor. The drainage of land puts it in a state to pulverize by drawing off the surplus water.)

"The great purpose of draining being, immediately, the improvement of the land, but ultimately, the promotion and improvement of vegetable production, the preceding considerations as to the fitness of the soil for germination may be well followed by a brief enumeration of the rules for the application of water to plants, which, as laid down by De Candolle, refer,—

"First, to the quality of the water used: that it should be well aërated; the presence of atmospheric air is good, but of carbolic acid gas much better. The next qualities desirable are, that it should contain fertilizing matters; the water should be as little muddy as possible; the temperature of the water is of importance, especially for hot-house plants: the water used in hot-houses is allowed to stand for some time before it is employed, in order that it

may have the temperature of the place; it is well that other water employed should stand for a time in the sun.

"Second, to the times of the application:—In the winter time there should be little irrigation, because the plants are then dormant, and water is then super-abundant. In spring time water is usually abundant. In summer it is wanting; and at that time the water should be given in the evening.

"Third, to the quantity of water to be applied, which should be varied according—

"(*a*) To the object of the culture:—When for leaves, more water should be given than when for flowers; less water should be given when for grains or fruits.

"(*b*) To the depths of the roots:—The application should be more frequent to the plants of which the roots are superficial; less frequent to deeper roots.

"(*c*) To the structure of the foliage:—Those which evaporate much (such as plants with large leaves) more frequently than perennials or plants with thick leaves.

"(*d*) To the consistence of the stalks and of the roots:—Roots with fleshy fibres do not thrive if too abundantly watered; at the same time they are injured by dryness. Tuberculous or bulbous plants, or plants with fleshy leaves, can bear a long-continued dryness, and therefore infrequent yet abundant waterings suit them well.

"(*e*) To the stage of vegetation:—It is important to bear in mind that the young germinating plants require light and frequent waterings; those that are in the height of growth abundant waterings; and when the fruit or seed is being matured the waterings should be infrequent. Those that have been transplanted require abundant watering.

"(*f*) To the nature of the soil, according to which these rules must be modified:—The lighter the soil the more frequent and plentiful must be the waterings. If it is a compact and clayey soil less watering will be required.

"(*g*) To the state of the atmosphere:—It will be readily conceived that the watering must be more frequent

when the temperature is high, the sky clear, and the air dry, and during drought."

In Arizona and other places where irrigation is required in order to raise abundant crops, the above information in the matter of watering plants will be valuable.

Stevens says on the benefits derived from good drainage :—

"The existence of moisture in the soil being easily detected by injurious effects on the crops ; the advantages derived from drainage are also indicated by its good effects on them. On drained land the straw of wheat shoots up with vigorous beard, strong, long, and so stiff as not to be easily lodged. The grain is plump, bright colored and thin skinned. The crop ripens uniformally, is bulky, prolific, more quickly won for stacking in harvest, more easily threshed, winnowed and cleaned. The straw also makes better food foı live stock. Clover grows rank, long and juicy, and the flowers large and of a bright colo·. The hay wins easily and weighs heavily for its bulk. Pasture grasses stool out in every direction, covering the ground with a thick sward, and producing milk and meat of the finest quality. Turnips become large and plump as if fully grown, juicy, and with a smooth and oily skin. Potatoes push out long and strong stems with long tubers, having skins easily peeled off, and their substance mealy when boiled. Live stock of every kind thrive, evince good temper, and are easily fattened, and of fine quality. Land is less occupied with weeds, the increased luxuriance of all crops checking their growth. Summer-fallow is more easily cleaned, and much less labor is required to put the land in order for manure and seed, and all sorts of manures incorporate more quickly with the soil. Thoroughly drained land is easily worked with all common implements. Being all alike, its texture becomes equal, and in consequence the plough passes through it with uniform freedom, and, moving in a free soil, it is able to raise a deeper furrow-slice, which, on its part, though heavy, crumbles down and yields to the pressure of the mould-board, into friable, mellow, rich-looking mould.

The harrows, instead of being held back at times, and starting forward and oscillating sideways, swing along raking the soil into a smooth surface, and entirely obliterating the horses' foot marks. The roller compresses and leaves the soil even and smooth, but the part below in a mellow state for the roots of plants to extend in."

Another authority says :—" Draining has not only been the means of increasing my crops, but they can be sown two weeks earlier and can be gathered in two weeks earlier than before the fields were drained. Experience shows that for every $100 spent in proper drainage there is a return in increased and better conditioned crops of fully 25% profit."

" Experiments recently conducted at the experimental station, Uniontown, show that the average yield of corn off drained land was 36.84 bushels per acre, whereas the average yield without drainage off the same land was only 24.02 bushels per acre. Drainage, therefore, must be credited with the increase of 12.82 bushels to the acre, or 54.4 per cent., because the conditions were the same, and there was neither excessive rainfall nor drought during the season."

A farmer in Ontario, who won the sweepstakes gold medal for the best farm in Ontario, says,—" Good drainage will add at least one-third to the product of the soil. You can work your farm much earlier in spring, and it removes all stagnant water from your land."

But why quote authorities? Does not every farmer know how great the benefit derived from drainage? Perhaps the wherewithal to do the work is not forthcoming? If it is good policy to borrow money at all, it is for drainage purposes. There is plenty of money can be got for about 6% on farm security; and if by draining his land the farmer can increase the value of his products one-third, he might easily afford 6% for borrowed capital wherewith to increase his annual income.

TABLE No. 7.—*Proportional Rate of Fall in inches every 10 feet.*

Rate of Fall.	Decimal.	Nearest Fraction	Rate of Fall.	Decimal.	Nearest Fraction
	inches.			inches.	
1 in 5,000	0.024	$\frac{1}{40}$	1 in 250	0.480	$\frac{1}{2}$
1 " 4,000	0.030	$\frac{1}{33}$	1 " 200	0.600	$\frac{3}{5}$
1 " 3,000	0.040	$\frac{1}{25}$	1 " 150	0.800	$\frac{4}{5}$
1 " 2,000	0.060	$\frac{1}{17}$	1 " 100	1.200	$1\frac{1}{5}$
1 " 1,000	0.120	$\frac{1}{8}$	1 " 90	1.334	$1\frac{1}{3}$
1 " 900	0.134	$\frac{2}{15}$	1 " 80	1.500	$1\frac{1}{2}$
1 " 800	0.150	$\frac{1}{7}$	1 " 70	1.714	$1\frac{7}{10}$
1 " 700	0.172	$\frac{1}{6}$	1 " 60	2.000	2.0
1 " 600	0.200	$\frac{1}{5}$	1 " 50	2.400	$2\frac{2}{5}$
1 " 500	0.240	$\frac{1}{4}$	1 " 40	3.000	3.0
1 " 450	0.267	$\frac{4}{15}$	1 " 30	4.000	4.0
1 " 400	0.300	$\frac{3}{10}$	1 " 20	6.000	6.0
1 " 350	0.343	$\frac{1}{3}$	1 " 10	12.000	12.0
1 " 300	0.400	$\frac{2}{5}$			

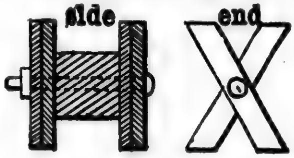


Fig 2.

Fig 1.

When it is difficult to get a leveler or land surveyor—as it often is in places where farmers are situated—a good enough method for obtaining the falls of drains can be extemporized thus: Obtain a pine scantling a little over 10 feet in length and about 4"x4" in size, and plane it down to an even thickness, and make it exactly 10 ft. in length, as shewn in Fig. 1. Now procure two rests, like the one illustrated in Fig. 2, much like two "sawhorses," and rest the scantling (illustrated in Fig. 1) upon them at some place in the field or land requiring to be drained.

Then, with an ordinary mason's level, set the scantling, by means of pushing the rests down firmly, level. By screwing in small nickel-headed screws, or driving bright tacks into the top of the scantling at A and B, the top of the scantling being level, you can sight between the two tacks or screws, the same as you would between the back

and foresight of a rifle, and this line produced is practically a level line. We say, practically a level line, because there is an allowance must be made for the earth's curvature when the sight extends to a distance. This allowance for curvature is always added to the fall, and amounts to about 8 inches in a mile, and only 2 inches in a half mile; and it is always proportional to the square of the distance.

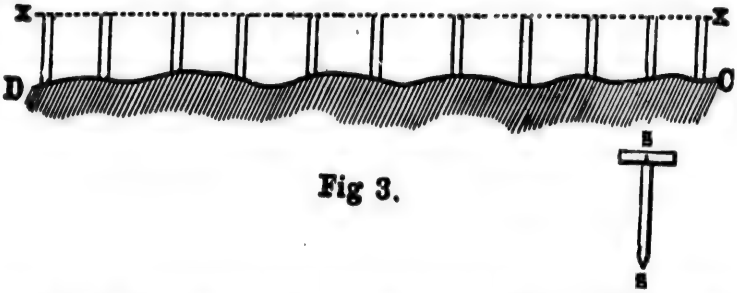


Fig 3.

Let C D represent the surface of a field. If our scantling (see Figs. 1 and 2) be set up level in the neighborhood of C, and a ten-foot pole be held at D, the height of the scantling being 5 feet, and the sight, through the two tacks or screws in the scantling, striking the pole just 1 foot below the top, the point D is 4 feet lower than the scantling near C. Upon measuring between the two points we find that from C to D is 1,000 feet: wherefore the fall is 1 in 250.

Now, to lay out the drain, we take about a score of sticks or palings about 5 or 6 feet long, with a cross-piece nailed on each (as illustrated in S S, Fig. 3). Then we stick into the side of the scantling (illustrated in Fig. 1) at B, at right angles, a common pin just so far below the level top as is given in table No. 7, applicable to the fall; and as this has been found to be 1 in 250, the distance below the top of the scantling at the end B is ½ an inch. Now, when we bring the foresight at A, which should be moved to the top corner—in line with the pin at B, we sight the line X X, Fig. 3. If the sticks or palings, S S, Fig. 3, be driven in at a number of points between C and D, until the tops of the cross-pieces be all in the line X X; then X X is parallel to the drain to be built. The reason

of this is because we have marked out a similar triangle on the scantling to that which a level line would form with the proposed drain. If the proposed drain is to be 5 feet deep, said number of feet is added to the distance from fhe surface of the ground to the top of each cross-piece on the line X X shown in Fig. 2, less 5 feet, the depths should be marked on a peg driven into the ground on either side of the sticks or palings, to prevent the drainers in their work from disturbing them. These sticks with cross-pieces on them are called "boning rods" by drainers. On account of the inequalities of the surface of the ground it is seldom that the "cuts" will be all 5 feet deep for a 5 feet drain. Some will be 4″x6″, some 5″x6″, and others 4″x11″. What is required is that the drain shall be exactly parallel to the line X X, illustrated in Fig. 3. Every drain, or section of a drain, must be laid on a true gradient downward to the outlet. A practical drainer, or one of the farmer's own family, can very readily lay out any ordinary drain as well as an engineer. In most parts of the country a leveler, or surveyor, can be got to lay out drains. There is hardly any necessity for a civil engineer to be employed for so simple a job, unless the drain or drains are intended to form a part of an extensive scheme, and then a practical civil engineer should be consulted. Be sure and get a practical one. An impractical professor won't do.

For the sake of brevity, in keeping with the idea at the start, this chapter now draws to a close.

It is well known that the centre of population of the United States has been gradually moving westward since 1790, until now it has reached close to Cincinnati, Ohio.

The population follows the virgin soils.

Many districts in the older settlements have become exhausted by over cropping. We need but keep our eyes open as we pass through the country to see thousands of acres in the older settlements lying waste. If we can do a little towards inducing people to properly drain and cultivate these extensive tracts of worn-out land we shall have accomplished a great work, and we think it can be done with great profit.

CHAPTER II.

It were waste labor to tell the farmer how to increase the products of his farm, unless facilities for transportation were provided.

As agriculture lies at the foundation, so does cheap transportation form no inconsiderable item in the farmers' prosperity.

The matter of building railroads is no longer a question that engages the attention of the few, but there is not a country between California and Nova Scotia; between the frozen North and Southern States, but men can be found who understand building them economically and scientifically.

No railroad, through any ordinary tract of country, ought to cost, for building and equipping, more than $20,000 per mile.

The farmers of one or two States, or Territories, could, without much difficulty, organize themselves into a company, subscribe for the stock, and build and own their own railroad. There are very few railroads built through a reasonably fertile country but pay a good dividend on their actual cost, if constructed with a view of serving the interests of the people.

We will illustrate what we mean by supposing the line to be built 100 miles long between the two ends. The line at $20,000 per mile would cost, including everything, about $2,000,000. Say, the shares were fixed at $20 each, and each farmer could take as many or few shares, up to 1000, as he pleased, which shares, with 10% paid up, would put us in possession of $200,000; an ample sum to pay for all legitimate preliminary work, location, legislation, etc. If required, the whole of the remaining 90 per cent. would be subject to "call" as the work progressed. For one share the farmer would pay not more than $20, and 100,000 shares sold, would realize ample funds to build and equip the line. Thus, a line could be had, and independent facilities could be had, by the farmers occupying a State or Territory, which could be operated

by themselves in their own interests. The Board of Directors might be annually nominated by the "Grange," or body of farmers occupying the District or Territory.

Some years ago a section of country in Canada was without railroad facilities. It contained a large number of farmers whose only means of reaching the nearest market was by team. The council of one of the counties met and voted a bonus of $250,000 to a company for building them a railroad. This was equal to the sum of $5,555 per mile. The Government subsidized the line to the extent of $6,000 per mile, so that there was available $11,555 per mile. The line but cost $16,000 per mile to build, so that the sum of $4,445 per mile was all the company spent in construction. Now why did not the farmers receive the Government subsidy and build the line themselves? To-day they would have had a good piece of paying property, and could have controlled it in their own way, most conducive to their own interests. Instead of which a large, powerful monopoly controls it and manages it in the company's interest.

The remedy is in the hands of the farmers. Your interests are greater than those of any other class. You hold the majority, not only of wealth, but of votes. It seems hardly necessary to name the remedy.

This chapter will end, for the sake of brevity, with a summary of the remarks of an intelligent writer in the Chicago *Tribune* of January last entitled "CORPORATION WRECKING."

He says corporations are wrecked :—

"1—By an official interest in the profits of railroad construction companies and by making contracts with them which are to the disadvantage of the corporation.

"2—By directorial interest in other railroads or corporations with running arrangements, consolidations and other agreements are made to the detriment of the common stockholders.

"3—By complicated systems of book-keeping, which, though not technically fraudulent, are misleading and deceptive.

"4—By the withholding of regular reports, statements and information for unfair advantages, and of which, in the absence of special legislation, common law does not take cognizance.

"5—By false reports put forth in an unofficial manner for individual advantage.

"6—By commissions and presents received by auditors and purchasing agents from parties of whom purchases are made.

"7—By manipulation in the stock market by means of combination or conspiracy among the managers, to the unfair disadvantage of other proprietors.

"The direct sufferers from official misconduct are private stockholders and investors, and from these classes untold millions have been extorted to swell the coffers of the few who are 'inside,' especially in mining enterprises. The most necessary and honorable business of building and operating a railroad has come to be properly looked upon as a 'scheme,' or even a 'game,' in which the management play with loaded dice. Those who win in these financial games are 'brilliant operators,' and 'Napoleons of finance,' and are imitated and envied by a numerous and ambitious following.

"Ring management is an incubus on legitimate enterprise, and an active, demoralizing element which is antagonistic to the very foundation of our social system. It furnishes the stock-in-trade of the Socialist and Anarchist, and is the keenest weapon which is wielded by all the impractical sentimentalists who wish to bring on the 'Coming Revolution,' and to destroy our present form of government.

"Many Socialists and Sentimentalists affirm that if our government were made more practical in its character, and would adopt and absorb the business of our great corporations, abuses of all sorts would virtually come to an end. All such reasoning is thoroughly fallacious, for (were it otherwise practicable) instead of any such desirable result, there would be an army of political abuses added to the present array of evils. The beautiful ideal which pictures the government as a great, immaculate

personality in economic management, is rudely shocked by the actuality, which finds that its active factors are embodied in selfish and scheming politicians.

"It seems evident that some system of governmental control is needed to include the following:—

"1—The compulsory making and issuing of monthly reports in a uniform manner and after a prescribed formula, the correctness of which should be affirmed by the oath of one or more directors.

"2—The removal of the reports from the possibility of interested coloring.

"3—Enforce all the usual moral obligations that appertain to trusteeship.

"4—Construe as bribery the receiving of any commission or presents by any auditor, purchasing agent, or official, which are given because of his official position.

"5—That it shall be unlawful, with heavy penalties attached, for any corporate official or manager to buy the stock of the company, except for the purpose of investment. Nor shall he sell the same unless he be the actual owner of the amount sold, and make a delivery of it; and he shall neither buy nor sell except after prescribed public notice.

"6—Require affidavits at stated intervals from each official and manager that he is not and will not make any speculative sales or purchases indirectly of the stock of his corporation, and that he has no interest in any such transactions which are made through any third parties."

CHAPTER III.

THE subject of village, town, and city drainage, is so intimately connected with farm-drainage, that we offer no apology for introducing it here; keeping to our idea upon undertaking this little work that—"Brevity is the soul of wit" and "boiling down" to a single chapter all that is definitely known upon the subject of sewerage.

It may be at once stated that the most economical way of draining farm-buildings, and most villages, is to carry all the water away to the most convenient natural outlet,—to some place in the neighborhood where the general drainage of the district empties itself,—by a system of drains, and keeping all the excreta, fluid and feculent matters, etc., for manuring purposes. We are of the opinion, from extended observations, that the "dry earth closet system" of deodorisation, would probably be the most economical, and fill the conditions of preserving the health and lives of people living in villages, or suburban, or even urban districts, more nearly than any other. It would be economical, because the gardens or orchards in the vicinity would utilize the productions of the water-closets, urinals, and cesspools with immense benefit.

A movable water-tight box or vessel placed in the water-closet to receive the excreta, etc., where, as often as used, dry earth or ashes could be taken out of a receptacle provided for them in the closet, and a few shovels full thrown upon them as occasion might require.

If a couple of railway rails, or pieces of oak in place of rails, were put down, and the box or vessel to receive the excreta, etc., set on small flanged wheels, it could be—provided a door were made in one side of the closet—easily run out and emptied when necessary, and its contents carted away, and the box replaced. There is scarcely any smell from this mixture, and in a very short time it is completely deodorised.

In towns and cities, on account of the denseness of the buildings, it is seldom that the "dry earth closets" are practical. It therefore often becomes necessary to construct a system of sewers.

The first thing to establish, as in all drainage works, is the position of the outlet, In sea-coast towns, of course, we find a point, where from the movement of the tides, currents, eddies, etc., the sewage will be carried out to sea and never be brought back again to pollute the beach or vicinity. Such a point can generally be found by an expert in a few days. This constitutes the best of all outlets. There hitherto has not been any device suggested

or proposed whereby the agricultural constituents of the sewage can be eliminated so as to leave a profit from the operation.

The next best outlets are undoubtedly the inland seas or lakes or large rivers. The main things to guard against are (1) the return of the sewage by storms or currents, to be thrown upon or against the shores and banks bordering upon the lakes or rivers in close proximity to the town or city to be sewered. (2) The pollution of the air or drinking water by the noxious effluvia, or by mixing their deadly germs with the source of supply.

As North America is so situated that large lakes and rivers abound; and for the purposes of commerce, most of the larger cities are located on their shores, consequently, an expert has generally little difficulty in the selection of a suitable outlet. If the sewage is to be emptied into a lake, the principal thing to determine in the first place—and one most times of easy attainment—is to find the direction of the currents, whether caused by storms, winds, etc., or by some peculiarity in the formation of its shores. After this has been determined, find a position for the outlet, where the sewage would never come back to pollute the shores, or find its way into the drinking water.

In large rivers, such as the St. Lawrence, Mississippi, Missouri, etc., the outlets are much easier found; for when the sewage is once in the river it is carried down by the current, and the only thing to guard against is the pollution of the air or drinking water of a community of people living below, somewhere on its course to the sea. Proper investigation by an expert will show whether any community below on the river will be injured by the sewage as it passes along.

A competent Civil Engineer should always be appointed with full control over works of this kind, where the lives and safety of the inhabitants depend upon the work being well done. It may be laid down as a fact, about which there can be no controversy, that improperly constructed or badly ventilated sewers are worse than none at all.

The intelligent aldermen, councillors and mayors of cities and towns, can always very materially assist a practical engineer by their suggestions and even counsel; and if they would observe the simple operations of nature they might correct his errors of judgment: but their business pursuits and training generally preclude their acquiring experimental knowledge of Sanitary and Civil Engineering.

We have observed in the long course of experience, that, in North America at least, the Chief Engineer of works is converted into merely an executive officer to carry out the directions and orders of committees of the corporations. The idea prevailing seems to be that, the members of civic or other governing bodies being elected to guard the public interest, therefore they should direct and control the execution of public works as well—that the election itself imparted to them greater knowledge than they had before—instead of leaving the design and execution of works to responsible salaried experts. It stands to reason where salaried officers are relieved of all responsibility by being made like mere wheels in a machine, that the committees who direct and control engineering operations should understand something of the governing principles of the science.

We therefore present the following facts from acknowledged authorities on Sanitation:

We deal with observed facts not theories, and do not account for the how, or why they are so.—We assert that wherever filth and dirt are found, there also are found the elements of disease.

There are already many works in print: many of them scientific: many unscientific, which any one of leisure can examine, and cull out, perhaps, clearer, briefer, and sounder sanitary maxims. But this little book is for common men who have not time to study the larger treaties; and besides we feel like any other man who writes a book, that this one will fill a gap in the numberless books already written.

A pure water supply is an indispensable element. Be-

fore any sewerage works are begun, this necessary life-giving element should be secured.

First, make an analysis of the water supply. Any good analytical chemist will be able to tell whether the water is pure and healthy or not.

"It is now certain that an impure water supply may be the cause of terrible outbreaks of cholera, typhoid fever, dysentery, and other allied disorders, but even doubts are widely entertained whether these diseases, or some of them, can possibly attain general prevalence in a town except where the faulty water supply develops them."

Extract from Dr. Simon's Report to the Privy Council, 1867.

When disease is prevalent and the diagnosis points to blood poisoning as the cause, it is well to remember that disease is often caused by excremental pollution of the soil. Water is poisoned by leaky sewers.

Sewage should not, under any circumstances, be allowed to leak through a sewer to poison the soil of our streets, or render the rainfall, which is pure when it leaves the clouds, the messenger of disease.

"Natural streams should not be arched over to form main-sewers; because a natural stream may drain a district very much larger than the area built over, and consequently a culvert (or sewer) of capacity to remove flood-waters in a wet season would be comparatively dry during a dry season, and any sewage then flowing in it would stagnate and evaporate, causing nuisance."—*Sir R. Rawlinson, Chief Engineer, Imperial Government Board.*

Besides this, if the sewer were constructed small enough to carry the whole of the sewage out it would not be large enough to carry the natural water of the district drained by it, during floods: and then, those whose lands, either inside or outside of the town, originally drained by the stream, would have recourse to the courts for redress. They would be entitled to damages caused by said floods. For the common-law, which is scommon-sense, allows no corporation or individual the right to impede or obstruct the natural drainage, and cause damage to private interests.

We do not think it necessary to say more on the subject of water supply. This manual is confined to the subject of drainage to a large degree. Water-works for the supply of towns and cities being subject to the laws of pure hydraulics, and not so complicated as the subject of general drainage, will form the matter of a subsequent manual.

DRAINAGE AS A PREVENTATIVE OF DISEASE.

The records of English Sanitary works, according to the medical health officers of the Privy Council, show, that properly constructed sewers reduced the rate of mortality from Typhoid fever 50 per cent, and from Phthisis 30 per cent; and the total of lives saved from drainage works has been fully 18 per cent.

"Statistical investigations made by professor Pettenkofer, show us that for every case of death in public institutions for the sick there are thirty-four cases of serious illness, so that the unnecessary deaths must be multiplied by that number in order to give you the minimum cases of preventable sickness. These cases of sickness last on the average 18½ days."—*Dr. Lyon Playfair's Address, delivered in Glasgow*, 1874.

In his inaugural address, as President of the Society of Civil Engineers, Mr. B. Latham informed us that in twenty years a sum exceeding £531,475, had been saved, in the estimated value of lives saved, as a result of his sanitary Engineering.

Dr. Chamberlain reports from a conversation with Dr. Richardson, acting secretary of the State Board of Health of Massachusetts, "that there they never have a fatal case of scarlet fever or diptheria, without finding some cause for it in defective drainage, ventilation, or bad sewerage of the dwelling."

Sewers Should be Self-Cleansing.—The prevailing opinion that brick sewers, on account of their roughness on the inside, retarded the velocity of the contents to such an extent as to cause them to choke up, is founded in error. The only way to prevent deposits on the inside of

any sewer is to give it a proper fall Both brick sewers and pipe sewers are equally subject to be blocked by the sewage if sufficient fall is not provided.

The gradients of sewers must be so proportioned that the sewage flowing down-grade through them must have sufficient velocity to prevent any settlement of the particles held in suspension. About three feet per second for main sewers, and five feet per second for small sewers, will prevent settlement of their contents if this velocity is kept up constantly.

The velocity which does the work is that at the bottom of a sewer, which is less than the mean velocity. (See Prony's experiments.)

It seems hardly necessary to say that the laws of gravitation control all motion. A sewer without a fall can give no motion to sewage. Sewers or drains without fall will eventually be choked with their contents. Not later than 1885, we were gravely told by one of the city authorities, in London, Ont., "that the question of fall did not matter much when pipe sewers were used." In February, 1886, the following spring, The London *Free Press*, said, "Recent sewers have been laid with so little fall that it has been found necessary already in many of the latest constructed ones to have them opened up and cleaned of the solid matter which they contain, which effectually prevented the flow through them."

By experiments we find that dirty water will not flow with the same velocity as clean water through the same channel. The velocity varies with the amount of solid matter held in suspension. Hence, molasses has a much slower velocity than water. Practical sewer engineers construct their own tables of velocities. The data being their own experience and observations, as the density is always in proportion to the solids held in suspension, and necessarily varies in different towns and cities.

Sewer Pipes.—Every pipe for use in sewer-work should be submitted to the analysis of the best analytical chemist in the town or city to be sewered. He should report upon its material. It should be practically impervious and not subject to be injuriously acted upon by sewage in any

degree. Earthenware pipes, salt glazed, are generally the best for all situations. Sewers up to eighteen inches in diameter may be used in all situations, but if larger pipe sewers are required, they should be laid in a bed of concrete for safety, as in some kinds of soil they require its supporting power to prevent probable collapse. Every sewer should be practically water-tight, from end to beginning, as the soil of our streets is often polluted by leaky sewers, and the effluvium disengaged is nauseous.

Portland cement nearly pure should be used for jointing all sewer-pipes.

The pipes themselves may be made of Portland cement and screened gravel. Use the cement two parts to one of gravel.

Putty should be never used to make joints. Lead pipes are subject to the injurious chemical action of acids and lime.

All lead pipes should have lead joints. Zinc pipes are certain to fail when subjected to the chemical action of sewage, and therefore are never used in first-class sewer work.

Bricks.—It has been found from experience in London, Eng., that the inverts of brick sewers wear out first. This is according to the well-known fact that the effective velocity is at the bottom of a sewer, and the scouring action of sewage tends to wear it out at the bottom first. The very soundest bricks should be selected for sewer work. Those made from what brickmakers call "strong clay" are usually the sounder. They should have a metallic ring when two of them are struck together, and the harder burnt should be selected for the invert of the sewer. Those partly vitrified by the action of fire should be chosen, and when laid with plenty of good Portland cement will make sewers practically water-tight. Brick work should be protected from water till the cement has thoroughly set, otherwise the soluble parts of the cement may be washed out, and the sewer held together with nothing but a rope of sand. A man can readily pick out the joints with his fingers when water gets admission to brickwork before Portland cement used in it has set, but

let it set first, and then it takes a cold chisel to remove it. This will account for the failure of some sewers built recently.

Cement.—Asphaltum is good for making joints, but Portland cement is most generally used.

The failure of some brickwork in sewers may be accounted for by the chemical action of sewage on some kinds of cement. Some sorts of cement are chemically changed in their properties, when they come into contact with the acids, ammonia, etc., found in sewage, and the sewer has nothing but the sand in its joints, which a man can easily pick out with his knife.

A good Portland cement will bear a tensile strain per square inch, after being set 7 days, of 350 lbs., and weigh about 112 lbs. per bushel.

It has the invaluable property of neither deteriorating by age or climate when kept dry.

The following is the usual ordinary composition of a good, sound, Portland cement (according to D. C. Collins, Esq., of England):

Lime	58.80	Alkalies	0.50
Silica	21.70	Magnesia	1.04
Alumina	9.82	Moisture	2.79
Oxide Iron	3.78		
Sulphuric Acid	1.57		100.00

A cement so composed, no matter by whom, will invariably give satisfaction in sewer-work. We wish to impress upon those who may read this manual the importance of getting a good cement for all sewer-work. However good a cement might be for hydraulic works in general, it may be totally unfit for sewer-works on account of the well-known chemical action of sewage upon certain substances.

There are many spurious cements passed off for Portland cement; and here, where the protective tariff raises the price of cement to the consumer it is well to be sure of the quality of what you buy.

Ventilation.—The remedy for noxious gases and foul air is dilution and dispersion by means of ventilation.

The gases in sewers and the foul, fœted vapors composing the miasma of organic corruption, are absolutely

deadly under certain conditions if not mixed with a large proportion of pure atmospheric air.

Even smallpox virus might be sufficiently diluted with air or water to be innocuous, and fevers cease to be contagious when we do not shut out of our houses and hospitals the air which has been so plentiously provided for us, as was proven by experiments of Dr. Fordyce years ago. The proceedings of the Royal Society of April 1877, contain a paper writen by Dr. Percy Frankland referring to "The transport of solid and liquid particles of sewer gases," giving as the cause of an outbreak of cholera which occurred in Southampton, Eng., in 1866, as the late Professor Parkes said, "the dispersion of infected sewage through the air produced by the pumping of the infected sewage and its discharge in a frothy condition down an open channel 8 to 9 feet long. The effluvium disengaged by this seething mass was overpowering. A virulent epidemic of Asiatic cholera broke out in a few days afterwards; 107 persons died from cholera in the neighborhood; in a fortnight after which a closed pipe was substituted and the cholera abated and the epidemic was virtually over."

This would indicate that open channels for the conveyance of sewage are very dangerous, contrary to the opinion expressed by an eastern man, "That when sewers are open and near the surface, the sewage in them is acted upon by the sun's rays and rendered harmless." We believe that an open sewer is an abomination. The idea that the action of the sun's rays would render harmless the abominable stench that would arise from the rapid evaporation of the sewage, seems to us absurd and not worth arguing about.

Ventilation is affected by temperature. A change of temperature will often develop such an expansion of the air in a sewer as to force, with resistless pressure, the traps of house-drains. Whether the temperature of the contents of sewers is increased by what is poured into them, or the temperature outside is increased by the sun's rays, the effect is equally dangerous; for when the inside is warmer than the outside, of course, the air inside expands,

and when the air is warmer outside than it is inside of a sewer, the air outside expands: this mechanical action continually going on has the effect of pushing out and drawing in, or of alternately compressing and dilating the air of a sewer, and if provision is not made for letting foul air escape and admitting a supply to take its place, the imprisoned air will escape at points of least resistence viz., into the houses: as 1000 cubic inches of dry air at 32° Fah., swells in bulk to 1100 cubic inches when the temperature is increased to 82° Fah., 10 per. cent. There are other things, such as the fluctuation in the volume of sewage at certain times, which causes compression and dilations of the air in a sewer, and renders ventilation necessary, but the expansions and contractions of the air from changes of temperature are so universal, and constantly recurring, that it seems almost a waste of time to refer to it at all.

It surely but needs common sense to tell us that if air expands by heat and is confined within a boiler, the air when heated and expanding beyond the resisting strength of the boiler, will force its way out at points of least resistance;so, if a sewer holds air imprisoned in like manner it will force its way into our houses by unsealing the traps of our house drains.

Increase of temperature causes the gases accompanying decomposition, which is then more rapid, to escape. Hence heat increases bad smells in a sewer, and cold lessens them.

Dr. Marcy, of New York, says, "There are many days and nights during the summer months especially, when our city is almost uninhabitable by the dreadful stench. Even closing the windows on hot and sultry summer nights does not exclude the poisonous smells, which penetrate everywhere, lurk in every place, and sow the seed broadcast of typhus, dysentery, cholera infantum, and the like."

Dr. Hammond, of the same city, says, "The sickening character of the emanations in question is so indisputable that I do not suppose it will be denied by any one who has been subjected to the horrible stench; it oppresses us

in the streets, disgusts us in our moments of relaxation, and, worst of all, it nauseates us at our meals."

If people would remember that the natural law of gravitation is not suspended for anybody's benefi ; that this very general and simple operation of nature governs all cases of ventilation ; and that the varying weights of air at different altitudes and temperatures, are the sole cause of currents, entering and escaping from sewers, as well as buildings, we should not have a badly ventilated sewer, building, church, hall, theatre, or other public building in our land.

Neither the system of forcing air into nor drawing air out of sewers, as experiments have demonstrated, can have anything but a very limited effect. The experiments of Sir Joseph W. Bazalgette, C. E., Colonel Heywood, C. E., and numerous other able experts in sanitary science, have amply shown the futility and impracticability of extracting foul gases from sewers by furnaces, fans, and all such appliances, as their good effects are very limited. Sir R. Rawlinson, Chief Engineer, Government Board, in England, has demonstrated that all main sewers should be ventilated at regular intervals of not more than 500 feet, or there will be great danger of their becoming flues up which the poisonous gases will rise through house-drains to find their outlets in the connected houses. He also remarks that tall chimneys, steam-boilers, furnaces, etc., may do some good in short lengths of sewer, but they cannot be depended upon to do service corresponding to their cost and danger, as sewers cannot be ventilated as coal mines are.

An Alderman, in 1886, got this motion through the Toronto, (Canada), City Council, "That the fire and gas committee do take into consideration the advisability of bringing in a Bill to provide that hereafter all persons erecting steam-engines in the city be required to connect the draught of the boiler with the public sewer, for the purpose of improving the ventilation of sewers." This motion was adopted, but whether the Bill has been brought before the Legislature or not, we know not.

Pipes carried up to the gable-ends of houses, may be

substituted for street ventilation in some cases, but their diameters must be at least 6 inches, and they must be located about every hundred feet; and they must in no case terminate near a window, chimney, or other opening, because in that position they would sometimes bring sewer air into the houses instead of taking it away.

It has been shown us that charcoal is both a deodorizer and a disinfectant; therefore if the ventilator up to the gable-end of the house were trapped with a tray of charcoal, the danger, if not altogether removed, would be greatly diminished. Dr. Letheby says, "Chemists have hitherto failed to separate and identify the miasma of organic corruption; but the charcoal absorbs and oxidizes the miasma of decomposition, when with air they are passed over it."

Those who have paid attention to and investigated meteorological phenomena, cannot have failed to observe that every current of air leaves a partial vacuum in its rear as shewn by M. Venturi, in 1797, hence there ought always to be two openings, where the air without hindrance could come in and go out of house-drains; one near the surface of the ground on the outside of the house, and the other at the top of the house, but not near the chimney.

The subject of ventilation, being so little understood by the majority of builders is the only reason for taking up so much space in dealing with it here. Sewerage cannot change the condition of bad ventilation, but may make them worse, by conducting the poisonous gases into our houses.

This brief summary deals principally with sewers built large enough to convey away the excreta, slops, water in cellars, and all the fluid and feculent refuse of dwellings with a portion of the rainfall; but there is another system, called the "separate system" which is usually adopted by towns and cities having no place to empty the sewage where it will no more become a nuisance. To turn the sewage into a small river or stream would pollute it to such an extent as to do injury to the general health of the people of the district, and lead to numerous

actions for damages, would, of course, be out of the question. In cases of this kind drains to carry away the rainfall should be constructed, and separate sewers for the conveyance of the sewage to a sewage-farm ought to be built. The sewage-farm should be selected at some place a distance from the city, and the soil, if practicable, should be of a porous nature to admit of downward filtration; as the principle of broad irrigation, combined with downward filtration, is pre-eminently suited for the disposal of sewage where better methods cannot be obtained: but according to the highest authorities, among them the keenest intellects, there has been, hitherto, no method discovered whereby from a financial standpoint the fertilizing elements of sewage can be abstracted with profit.

When it is settled to have a sewage-farm, plenty of land should be secured to guard against saturation.

All sewers should be regularly flushed with plenty of water. This is indispensable. Not a few buckets of water here and there thrown into the sewer; or any ordinary flushing from the hose will do; but by impounding a quantity of water and suddenly liberating it. The volume of water so liberated should be in proportion to the size, and the work to be done in the sewer.

We were called upon to design and construct a system of sewers for the city of Winnipeg, Manitoba, in 1884.

The city plot is almost a dead-level, so that in order to obtain a proper velocity for the sewage, we were compelled to dig the trenches for the sewers over 10 feet deeper near the out-falls than at their upper-ends. The sewage at present empties into the Red River, which runs by the city at an average velocity of over 3 miles per hour. In our last printed report to the Mayor and Council of the City of Winnipeg, it is written, "I must call your attention again to the great importance of keeping the sewers flushed with plenty of water. Without this they will become simply breeding-places for infectious diseases. As I have pointed out before in previous reports, a daily supply of water for flushing purposes is necessary so that each day's sewage may be removad from the city on the day of its production and pass

off before decomposition sets in, and not allowed to settle and fester in the sewers." And, "To say as some citizens have said, 'that sewers should not be built in a year or two, but should be built gradually, so as to give employment to home labor through many successive years,' is just one of those remarkable fallacies attending the opinions of men ignorant of simple sanitary matters, though learned in many other respects. It is nearly equivalent to saying that typhoid fever, diphtheria, and all forms of zymotic diseases should not be got rid of in a short time, but should be banished gradually so as to further the sale of drugs and medical attendance through many successive years.'"

If sewers were designed and built by the Gods, they would not operate themselves. Like a watch, they want occasional winding up and cleaning. The fact of their being able to do a certain work does not invest them with living and thinking attributes. The man who forgets to wind up his watch and finding it stopped, blames the watchmaker, is not more unreasonable than some civic bodies in our land.

In conclusion we say that it is not the robust man, who can eat, drink, and sleep anywhere, and under any circumstances, who suffers as a general thing from foul air and gases escaping from sewers. But it is the weak, invalids, and little children who cannot help themselves. The cause of so many pains and sufferings, anxious watchings and heartaches, might be prevented.

What a multitude of little children might be saved? Those whose bright lives fade from the earth by *cholera infantum*, etc., would be with us to-day with their rippling laughter to cheer us on our way.

America is the grave of little children.

People will never awake to the importance of sanitary matters until the duty of sanitation is incorporated in our laws. And why may it not be so? The greatest of all human legislators, who, in addition to his duties as commander-in-chief, after having led, victoriously, three millions of slaves to freedom, gave them sanitary laws which we might adopt to-day with immense benefit.

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